

NATIONAL TRANSPORTATION SAFETY BOARD

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



October 21, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-042

1. ACCIDENT INFORMATION

Place : Saginaw, Michigan
Date : August 3, 2019
Vehicle : Cessna A185E, N5806J
NTSB No. : CEN19LA249
Investigator : Craig Hatch, AS-CEN

2. COMPONENTS EXAMINED

Remnants a crankshaft assembly
Pieces of a connecting rod assembly

3. DETAILS OF THE EXAMINATION

On August 3, 2019, about 0910 central daylight time, a Cessna A185 airplane conducted a forced landing about 14 miles southwest of Saginaw, MI. The pilot and three passengers received minor injuries, and the airplane sustained substantial damage. The pilot reported that during cruise flight, the engine experienced a loss of power. He selected a road for the forced landing; however, the airplane impacted a power pole and electrical wires during the landing. Examination of the accident site revealed the airplane came to rest inverted, with substantial damage to the fuselage and both wings.

Pieces from the Continental IO-520 series engine crankshaft were secured and sent to the NTSB Materials Laboratory. Figure 1 shows the remnants of the crankshaft assembly, as received. The crankshaft had fractured at the web between the #2 connecting rod journal (C2) and the #2 intermediate main journal (M2).¹ The airplane was recovered to a secure facility for further examination.

Figure 1 shows the two halves of the crankshaft assembly, as received. Except for the C1 journal, all the connecting rods and caps were still affixed to their respective journals upon receipt. Figure 2 shows the aft fracture surface of the fractured web near the M2 journal. The connecting rod adjacent to this fractured area (C2) was still affixed and able to be rotated about its journal. This web fracture surface exhibited rounded,

¹ Teledyne Continental Motors (TCM) crankshafts journals are numbered from the rear of the engine to the forward. Main and cylinder journals are numbered independently.

flattened features, consistent with smearing, batter, and other types of post-fracture damage.

The forward flange of the propeller exhibited a serial number marking stating, "F109804N". The flange was undamaged, and it contained eight propeller bolt holes—two sets of three together, located 180° from each other, and two single ones located 180° from each other. All the holes were the same size.

In contrast, the forward mating web fracture surface was relatively undamaged, as illustrated in Figure 3. The center of the fracture surface was generally flat, with some vertical gouges consistent with post-fracture impacts. The sides of the fracture surface exhibited material folded inward over the fracture surface. This was consistent with post-fracture smearing of the sides of the fractured web being deformed back over the fracture surface. The smearing on the left side of Figure 3 also exhibited banded coloring from yellow to violet to blue, consistent with heat tinting of this side of the web.

Figure 4 shows the adjacent C2 journal to the aft side of the fractured web. The connecting rod at this position, which contained a severed and missing nut on one side, was disassembled and removed. This journal exhibited indications of circumferential wear marks, consistent with rotational wear around the journal. The oil hole in Figure 4 was plugged with the remnants of the oil lubrication tube. The tube material was smeared and flattened over the journal surface surrounding the hole, consistent with protrusion and deformation of the tube between the journal and mating bearings.

Figure 5 shows the removed C2 connecting rod, rod cap, and bearings, as received. The lower portion of one of the attachment bolts was still present inside one of the bolt holes of the cap; the other bolt was not present. The inside surfaces of the cap and rod did not exhibit any features consistent with wear or damage.

Figures 6a and 6b show the rod bearings from the inside and outside surfaces, respectively. Both bearings exhibited circumferential wear marks on the interior and exterior faces. One of the bearings exhibited a 0.25 inch wide by 1.5 inch long area with gouging and material spalling. The location and width of this gouging was consistent with smearing of the oil lubrication tube in the journal shown in Figure 4. The opposite bearing exhibited outward (longitudinal) deformation outward, perpendicular to the bearing rotation direction. This deformation was visible on both surfaces of the part.

Returning to the crankshaft web fracture surface, the M2 journal is shown from opposite sides in Figure 7 and 8. The initiation side of the fracture surface was located approximately 0.125 inches from the journal surface, along the journal-to-web radius. These surfaces show indications of light wear, but no indications of plastic deformation in the form of gouging, smearing, or material loss. As shown in Figure 3, there were indications of circumferential wear marks, consistent with rotational wear around the journal. The bearings from this location were not sent to the NTSB Materials Laboratory, as they were reportedly found in the oil sump, consistent with having fractured and deformed repeatedly after fracture of the crankshaft.

The forward web fracture was sectioned from the rest of the crankshaft remnant. This piece was cleaned with soapy water, acetone, and ethanol. Figure 9 shows a closer view of the undamaged regions of the crankshaft web fracture surface. The fracture surface exhibited crack arrest marks, consistent with crack propagation from the top to the bottom of the figure.

Near the crack initiation region, on the top of Figure 9, several ratchet marks were observed. As shown in Figure 10, these marks were adjacent and perpendicular to the journal-to-web radius. Much of the surface material in this area had been damaged by smearing, manifest as angled horizontal streaks in the figure. Figure 11 shows a closer view of the area between two ratchet marks. Features such as river patterns were present and oriented consistent with propagation outward and downward in the figure from initiation sites on the edge. These ratchet marks were consistent with multiple cracks that coalesced during early propagation of the crack.

The web fracture surface was examined using a scanning electron microscope (SEM). Figure 12 shows a typical area of the fracture surface in the progressive cracking region. This figure shows fatigue striations, consistent with fatigue crack propagation. Figure 13 shows a closer view of these striations, showing consistent spacing, along with limited secondary cracking.

The crack initiation sites of the fatigue crack were examined, such as the one shown in Figure 14. While many had been obliterated by post-fracture smearing, this initiation site was undamaged, located between two ratchet marks with the edge intact. As shown in the figure, there were no indications of material defects, such as inclusions, corrosion pits, or voids. There were some indications of streaks or microwear marks along the fracture surface edge. Some parallel microcracks were present in this initiation site.

The chemical composition of the sectioned crankshaft web was examined using x-ray fluorescence (XRF) and energy dispersive x-ray spectroscopy (EDS). From the data obtained using these techniques, the crankshaft was found to be consistent with Type 4340 alloy steel. The hardness was inspected per ASTM E18.² The hardness averaged 40 HRC.

A portion of the web fracture surface was cross sectioned, mounted, polished, and etched with 2% Nital to examine the microstructure. Figure 16 shows a typical cross section of the web (unfractured) surface. The interior microstructure exhibited a lath microstructure inside polygonal grains, consistent with a tempered martensite microstructure, typical of this alloy chemistry and hardness.

The surface shown in Figure 16 exhibited a thin white layer. This layer was inspected using EDS, and it contained an elevated amount of nitrogen. These features were consistent with a nitrided case hardening, as prescribed for this part. The cross

² ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

section was inspected using microindentation hardness per ASTM E384.³ The effective case depth was found to be 0.01 inches.

Figure 17 shows a cross section through the fracture surface. This exhibited a different type of white layer, exhibiting cracking perpendicular and parallel to the fracture surface. The area under this region also exhibited more light-colored phases than that further inward. This white layer was consistent with a region of untempered martensite. This phase can form when the region is heated above 727 °C and then rapidly cooled.

A closer look further into the core interior of the web segment microstructure revealed thin elongated microcracks, often oriented parallel to each other, as typified in Figure 18. A closer view of one of these cracks is shown in Figure 19. These cracks were oriented along the forging direction, typically running along the laths of the tempered martensite, rather than along the prior austenite grain boundaries.

A portion of the propeller flange was sent to Continental Aerospace Technologies for additional testing, as detailed in Appendix A. A further section was cut, notched, and then fractured in a vise using a hammer. The generated fracture surfaces were examined using a SEM, and the fracture features included 'planar dimple features.' According to the report, these features were consistent with 'thermal damage of the microstructure.'

Erik M Mueller
Materials Research Engineer

³ ASTM E384 – *Standard Test Method for Knoop and Vickers Hardness of Materials*. ASTM International, West Conshohocken, PA

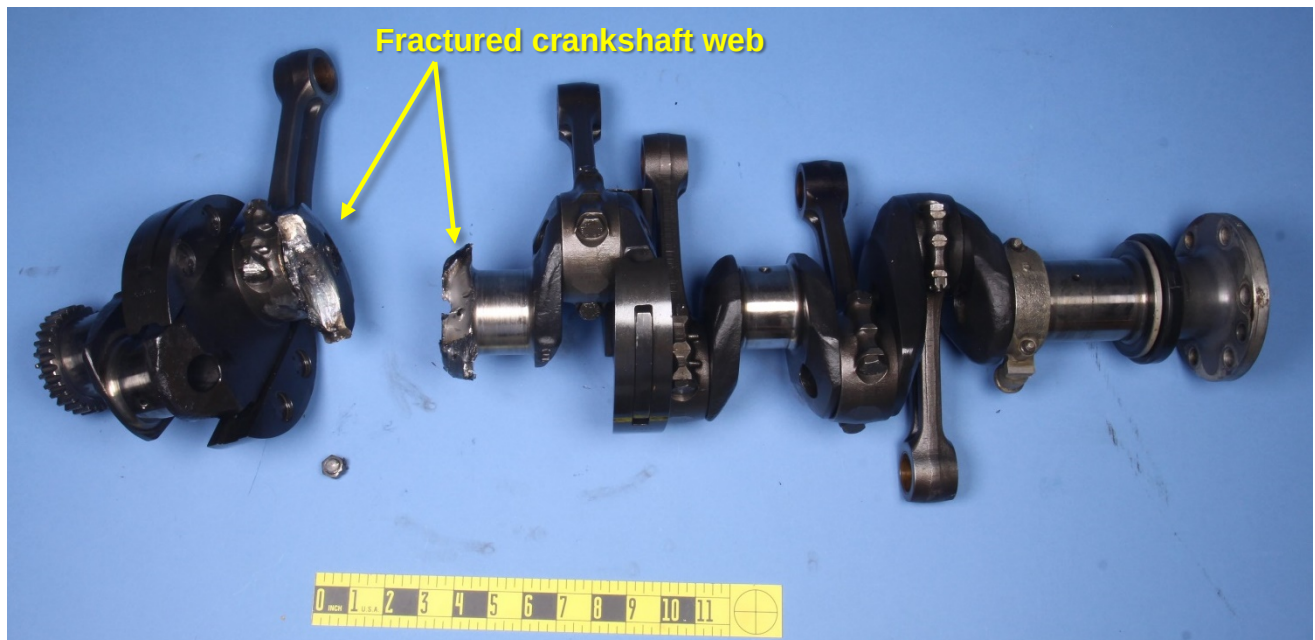


Figure 1 – The fractured pieces of the crankshaft assembly, as received.



Figure 2 – View of the aft fractured piece of the crankshaft assembly, viewed forward looking aft. The fracture surface across the web adjacent to the #2 connecting rod journal is visible.

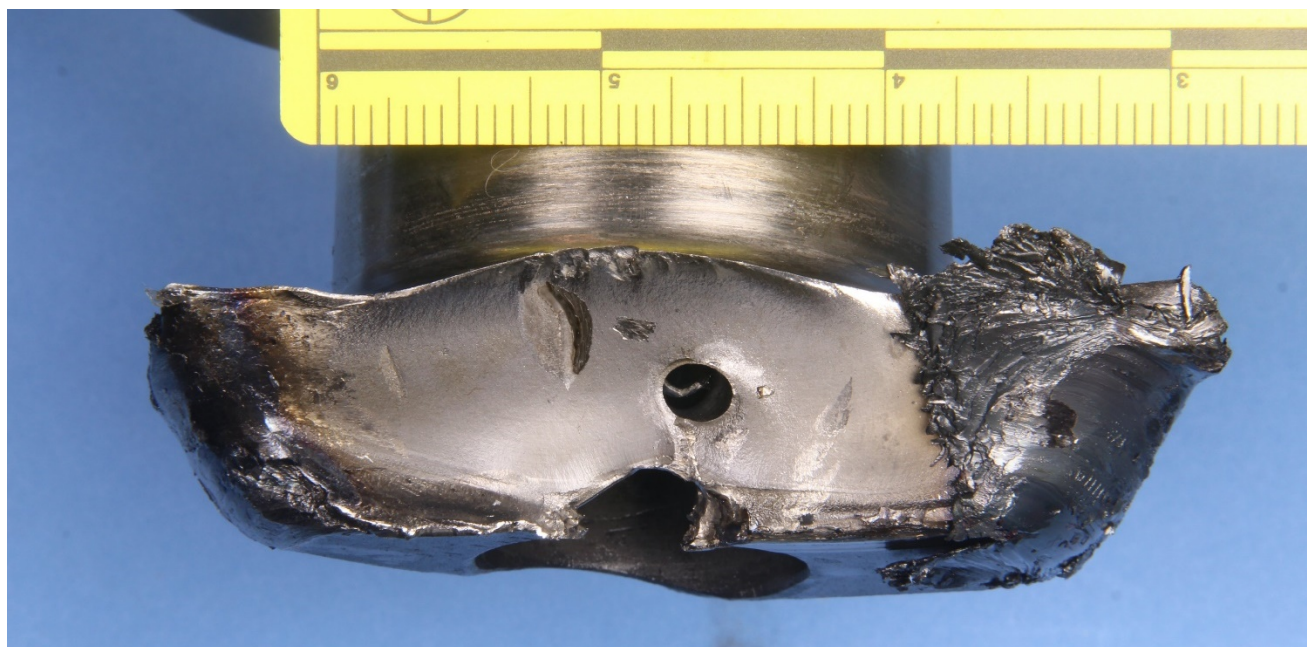


Figure 3 – View of the forward side fracture surface across the web at the M2 journal.



Figure 4 – View of the C2 journal adjacent to the forward side of the fractured web, showing a smeared lubrication tube in the oil lubrication hole, after removal of the connecting rod.



Figure 5 – View of the connecting rod and bearing from the C2 position, after disassembly.

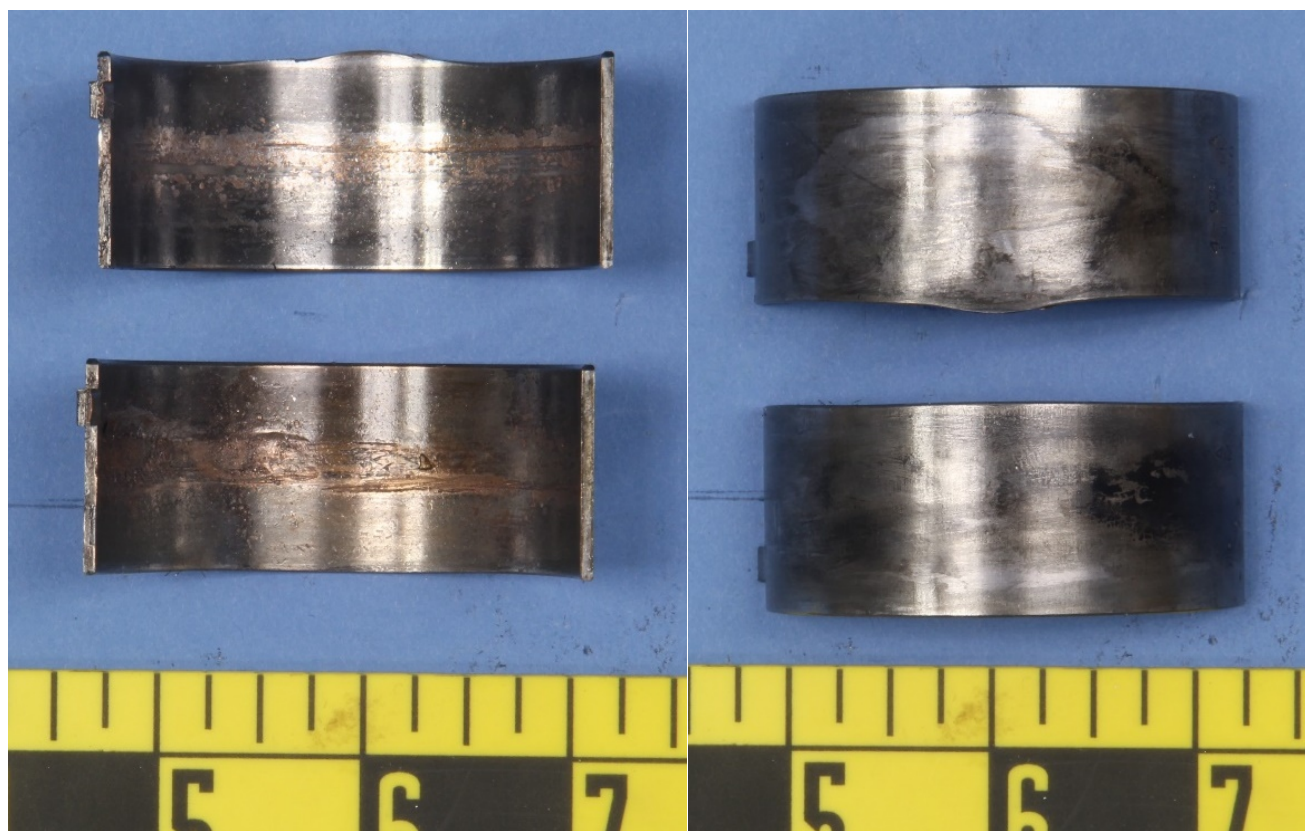


Figure 6 – View of the #2 connecting rod bearings viewed from (a) the internal and (b) exterior bearing surfaces.

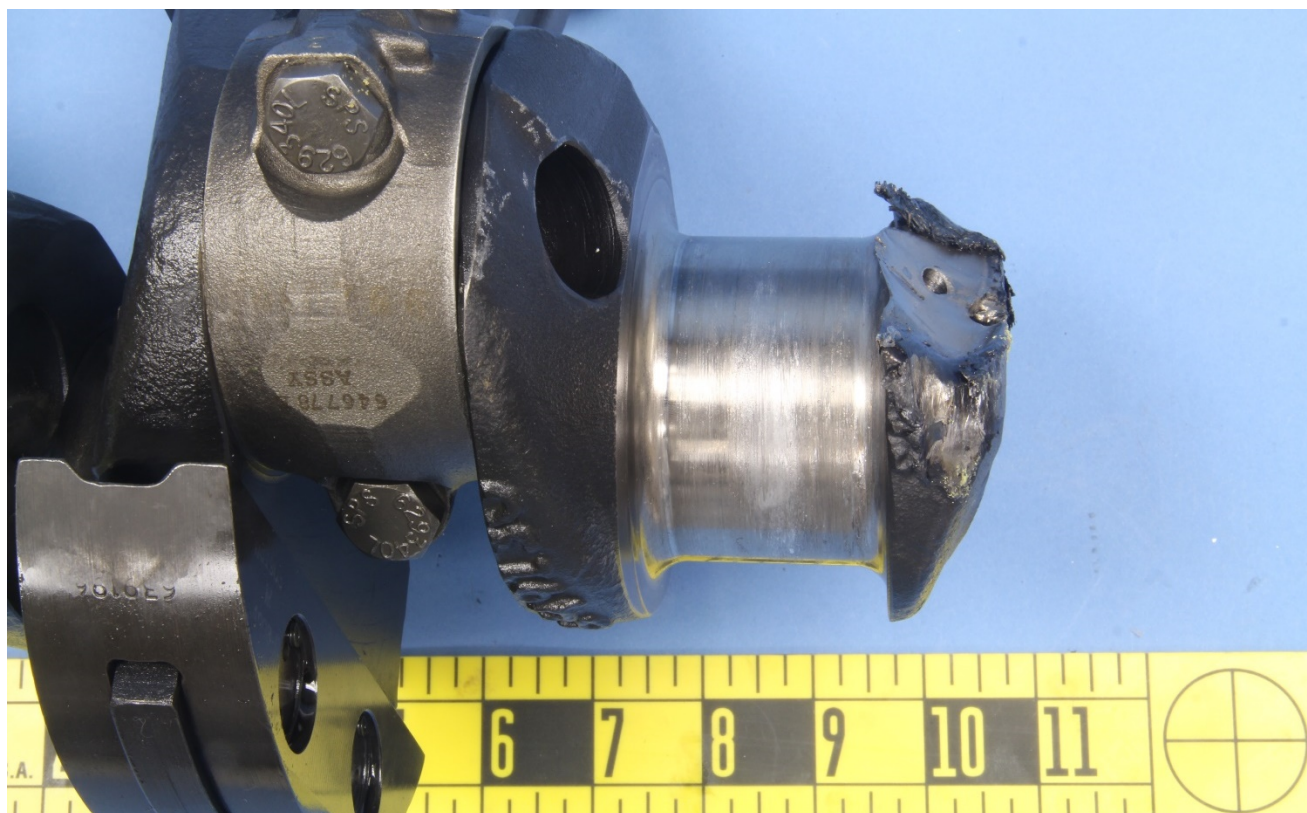


Figure 7 – View of the M2 journal adjacent to the fracture through the crankshaft web.



Figure 8 – View of the M2 journal from 180° opposite that of Figure 7.



Figure 9 – View of the forward fracture surface of the fracture web, after sectioning.

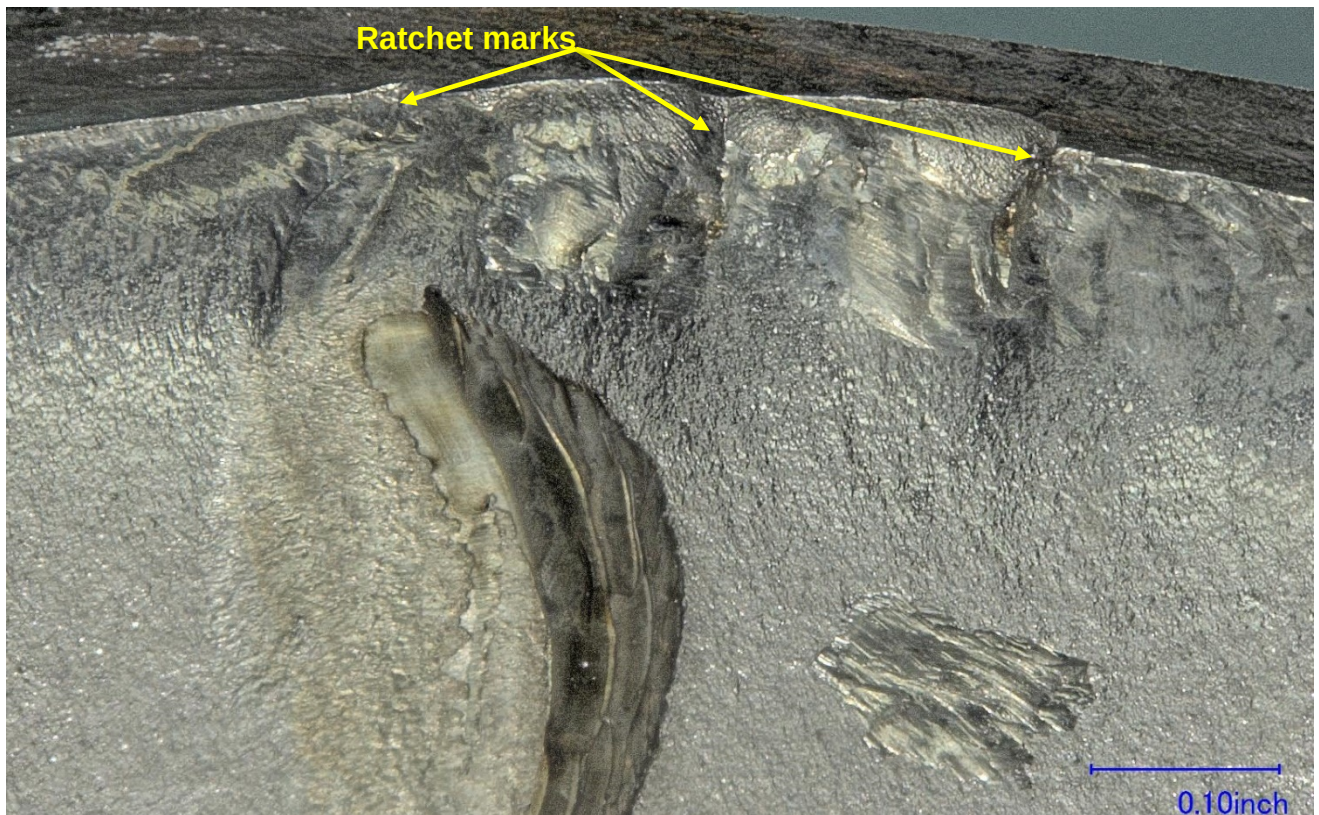


Figure 10 – Closer view of the top of Figure 9, showing 3 ratchet marks.

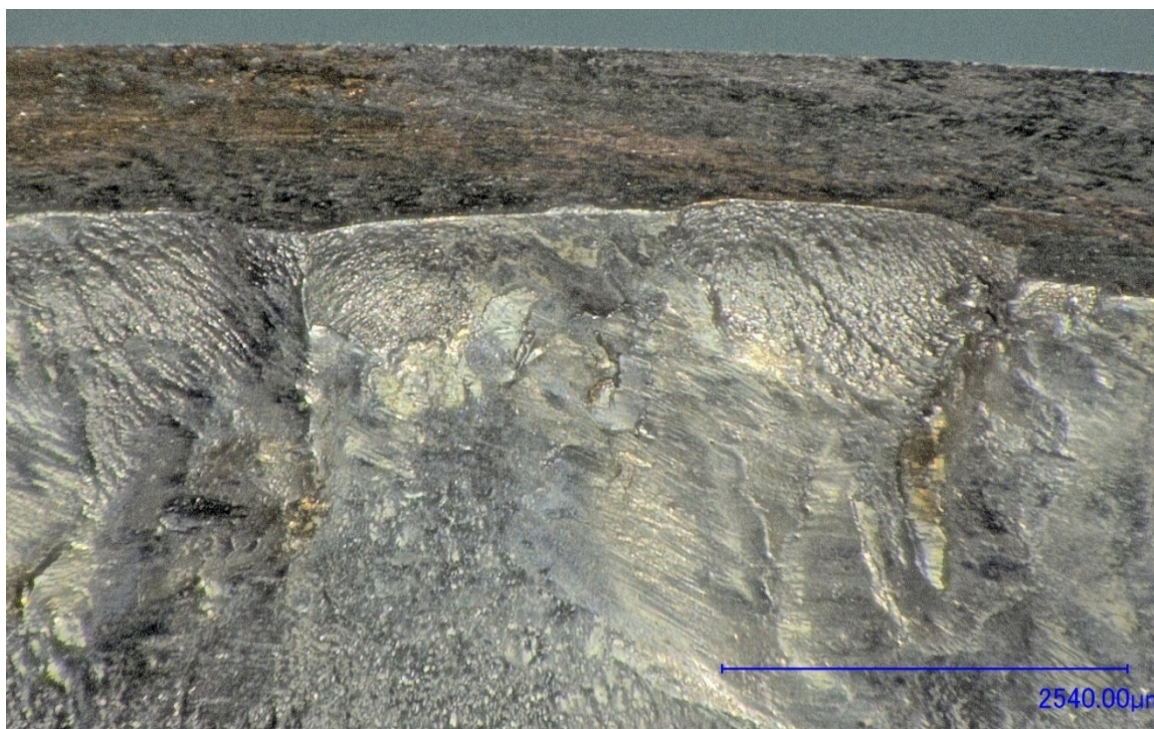


Figure 11 – Closer view of a crack initiation site between two ratchet marks.

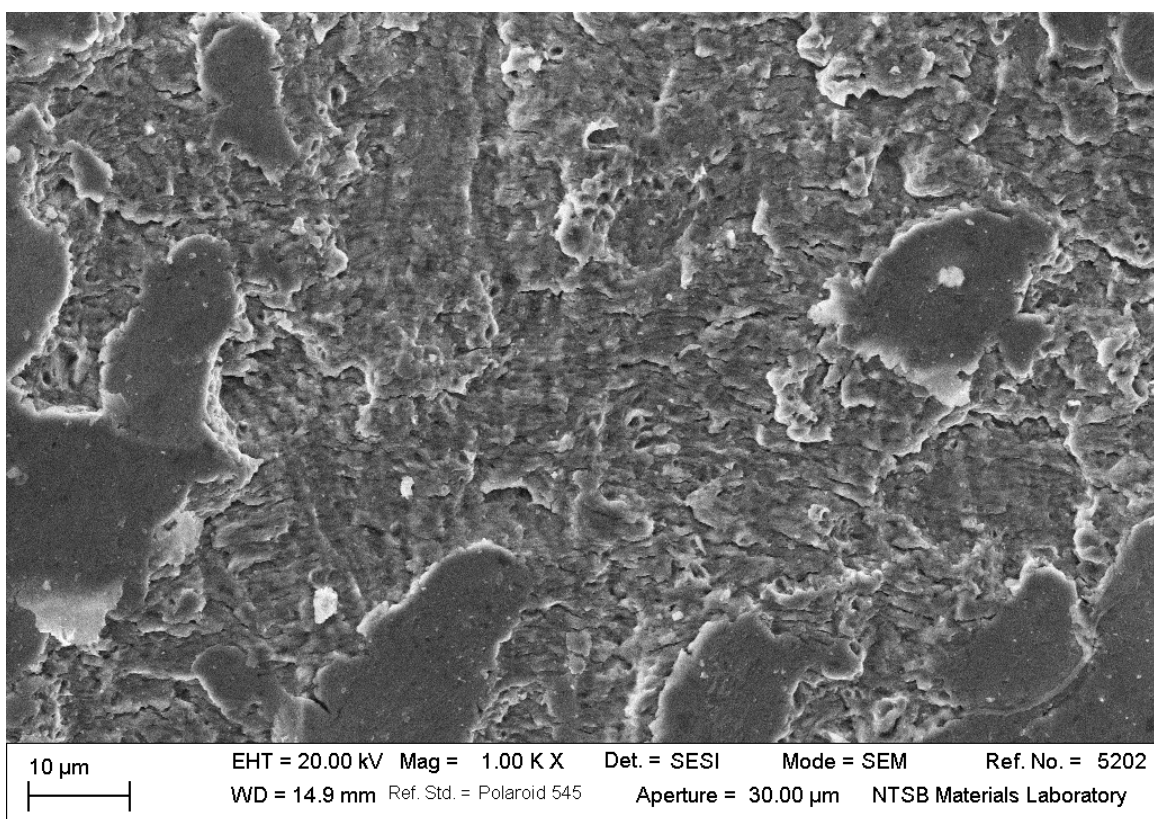


Figure 12 – Secondary electron (SE) micrograph of fatigue striations on the web fracture surface.

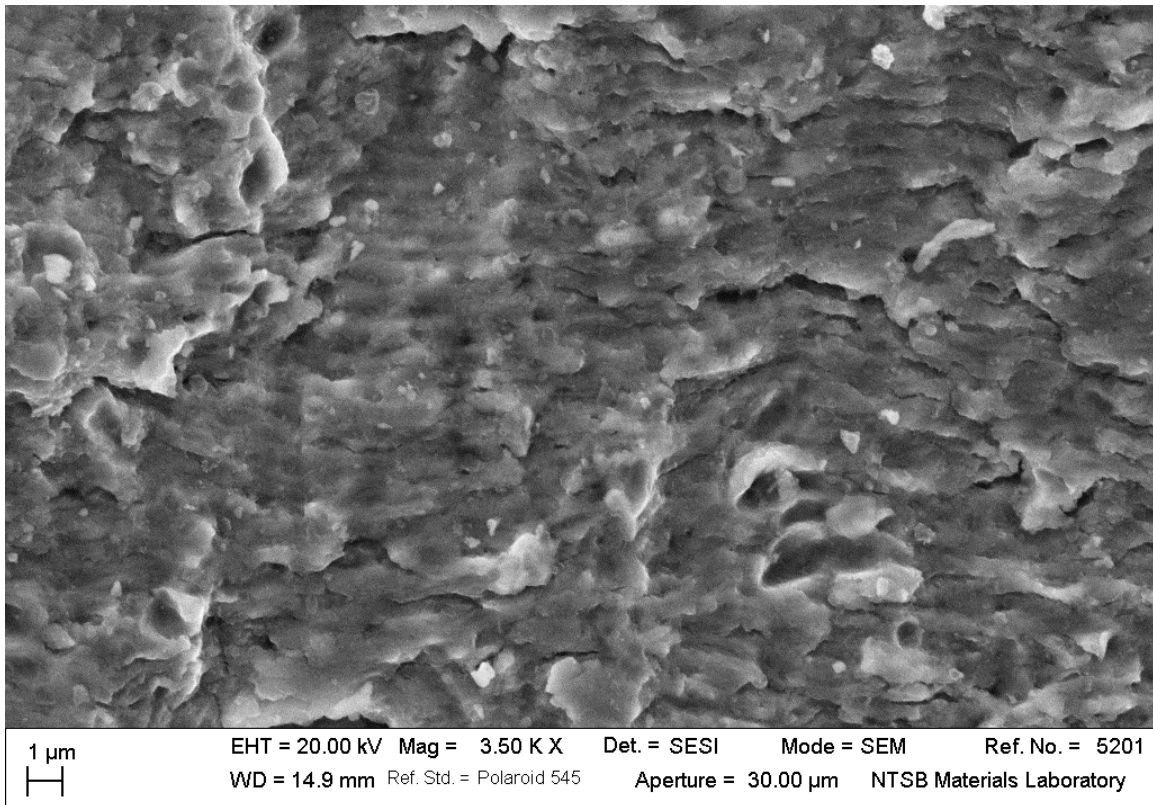


Figure 13 – SE micrograph of a closer view of the striations in Figure 12.

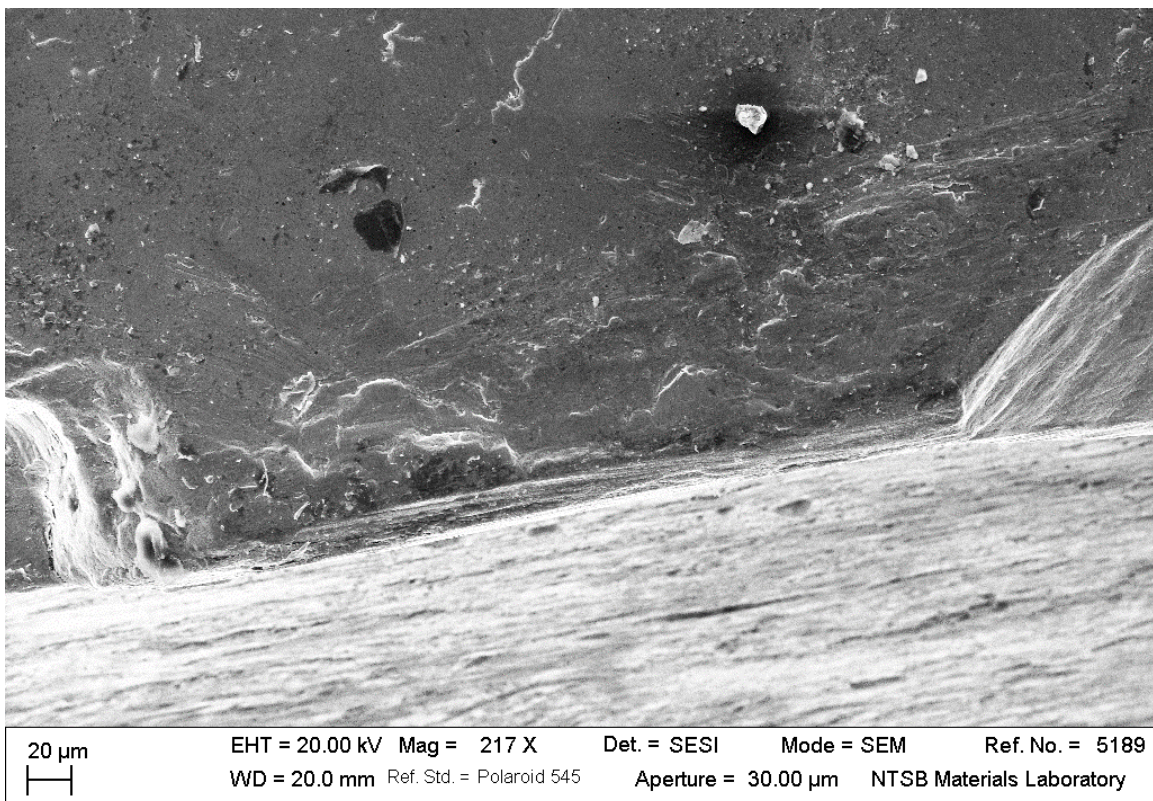


Figure 14 – SE micrograph of one of the fatigue crack initiation sites.

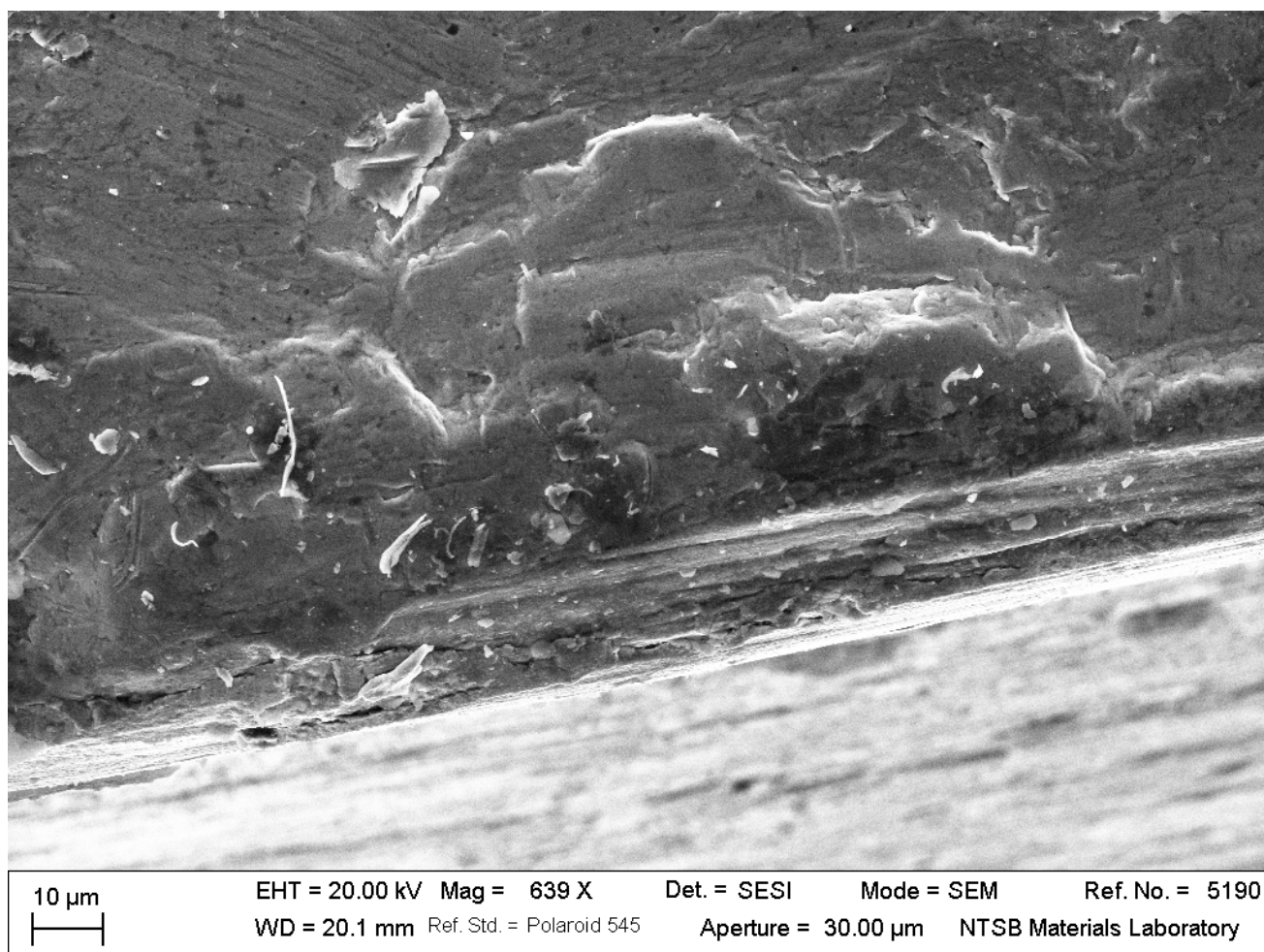


Figure 15 – SE micrograph of a closer view of the initiation site in Figure 14.

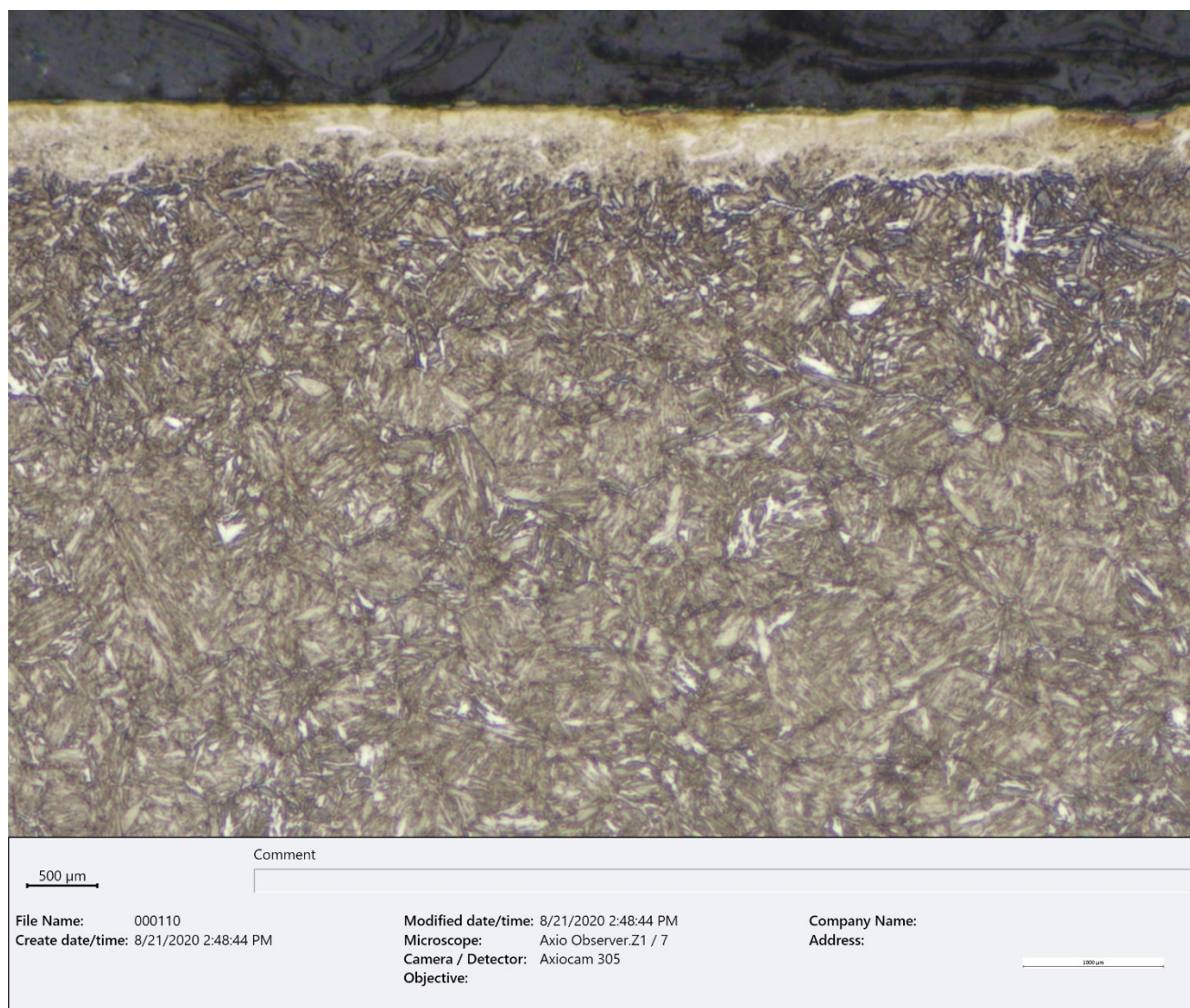


Figure 16 – Bright-field (BF) optical micrograph of the surface of a cross section through the web, showing a surface nitrided layer, and underlying tempered martensite microstructure (~200X, etched 2% Nital).

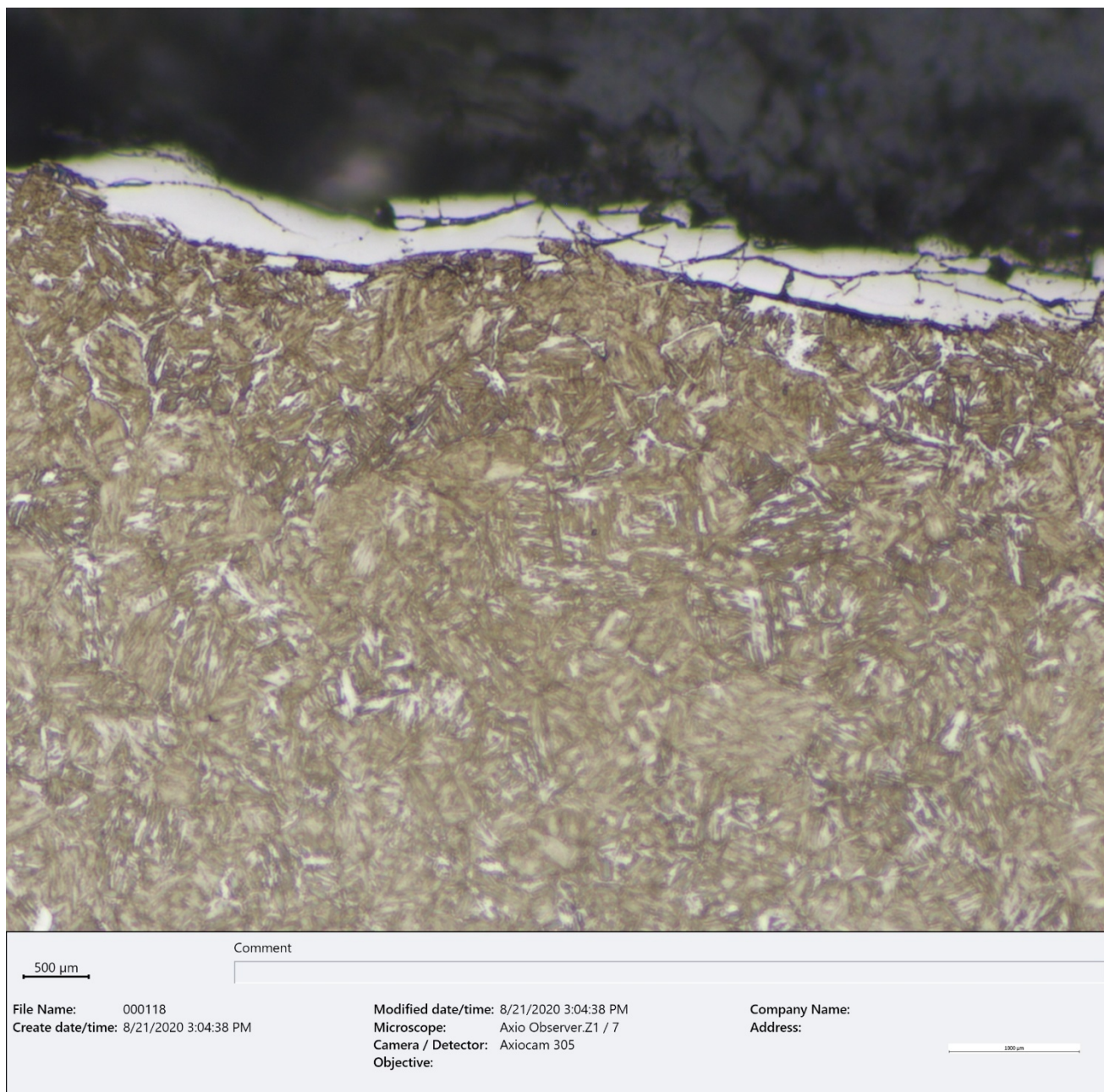


Figure 17 – Bright-field (BF) optical micrograph of the surface of a cross section through the web, showing an untempered martensite layer on the surface, consistent with exposure to locally elevated temperature (~500X, etched 2% Nital).



Figure 18 – BF optical micrograph of a typical area of the crankshaft web microstructure, showing tempered martensite, and thin elongated cracks (~200X, etched 2% Nital).

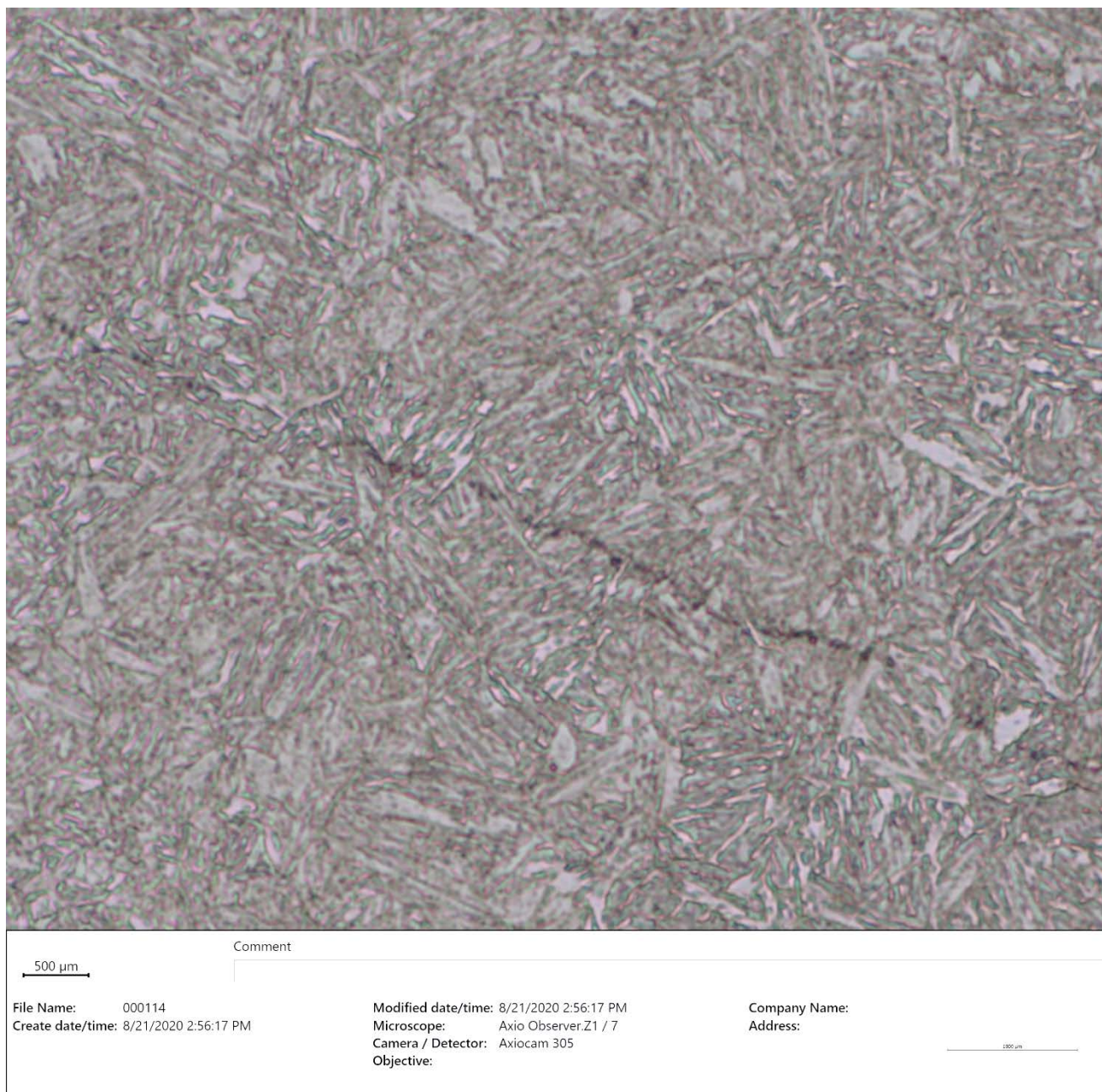


Figure 19 – BF optical micrograph showing a closer view of one of the microcracks in Figure 18, (~1000X, etched 2% Nital).

APPENDIX A

Continental Aerospace Technologies
Metallurgical Report ML N5806J

Report number: ML N5806J	
Date: 9/18/2020	
 METALLURGICAL REPORT	<u>Distribution</u> 1] 
Subject: Crankshaft section	

A section of crankshaft from NTSB Investigation No. CEN19LA249 was presented for analysis. The aircraft concerned had tail number N5806J, and the serial number on the flange of the crankshaft was F109804N.

Core hardness of the section measured 39 HRC and the nitrided surface measured 73HR30N. Both hardness results are typical for finished crankshafts.

The section was cut and notched for fracture analysis as shown in figures 1 and 2. The notched part was fractured in a vise with a hammer as shown in figure 3.

A scanning electron microscope was used to examine the fracture surface from 300X to 3000X per MSB00-5D. Regions containing the shallow planar dimple features were identified, indicating thermal damage of the microstructure. Figures 4-7 show these areas that were identified.

Conclusions:

- 1] Fracture shows several shallow planar dimple areas per MSB00-5D.
- 2] Surface and core hardness met requirements.

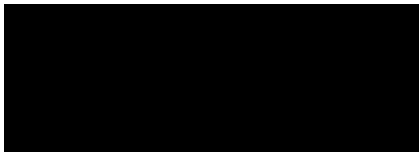
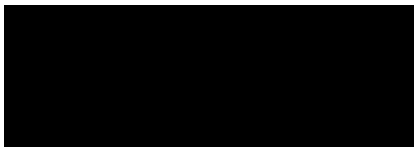




Figure 1 Section of crankshaft sectioned and notched for fracture.



Figure 2 Notched for fracture



Figure 3 Fractured section

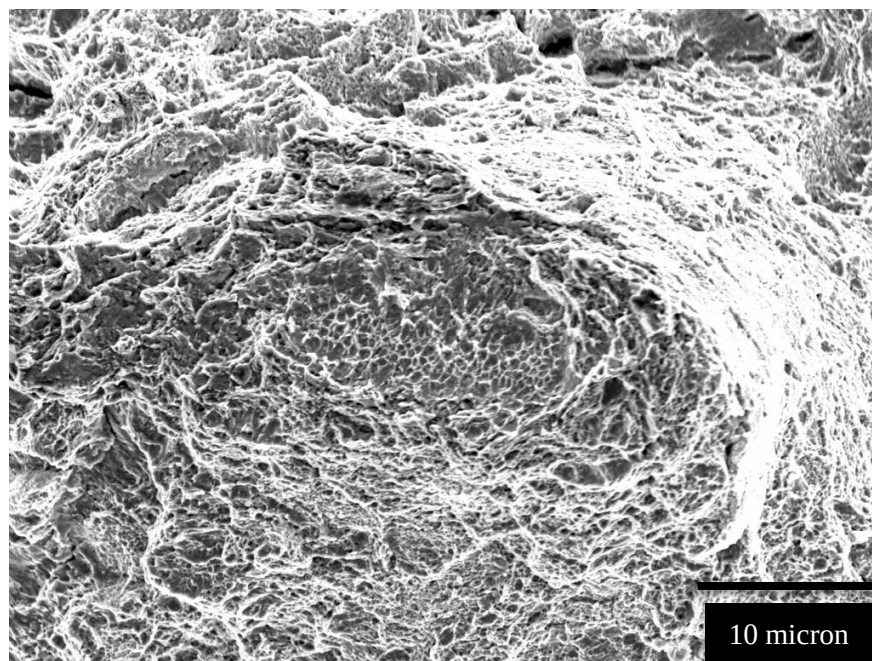


Figure 4 Shallow planar dimple feature

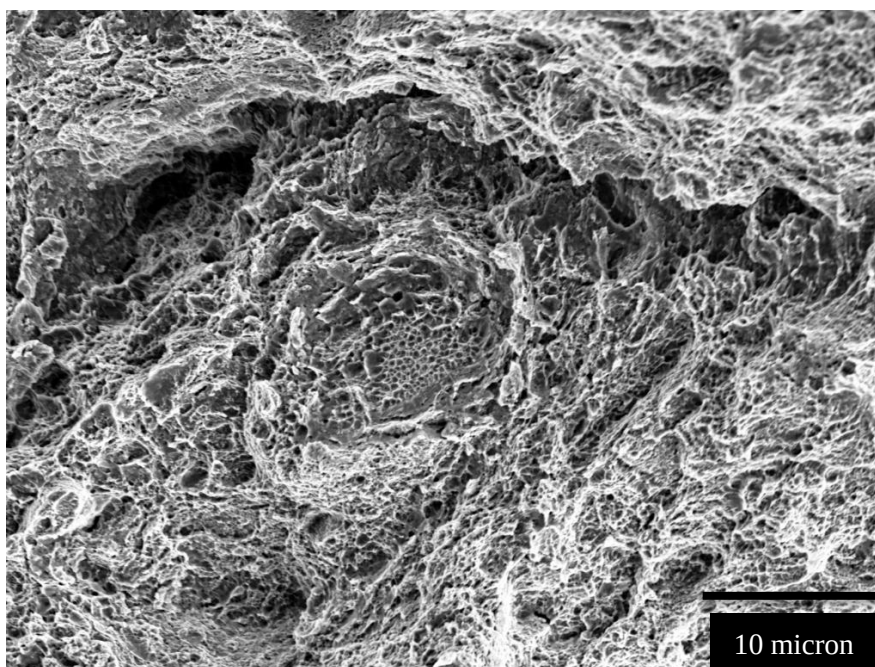


Figure 5 Shallow planar dimple feature

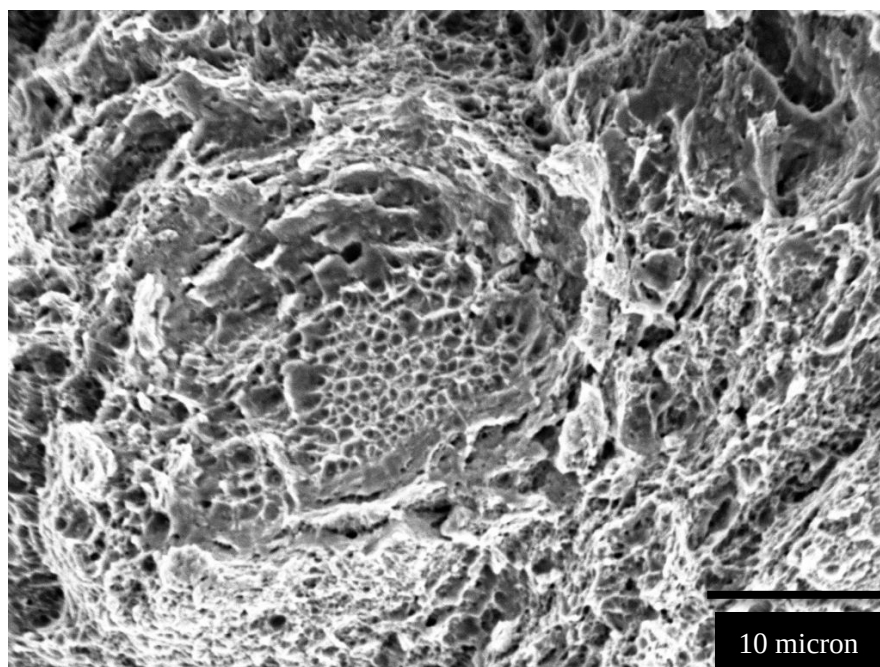


Figure 6 Shallow planar dimple feature

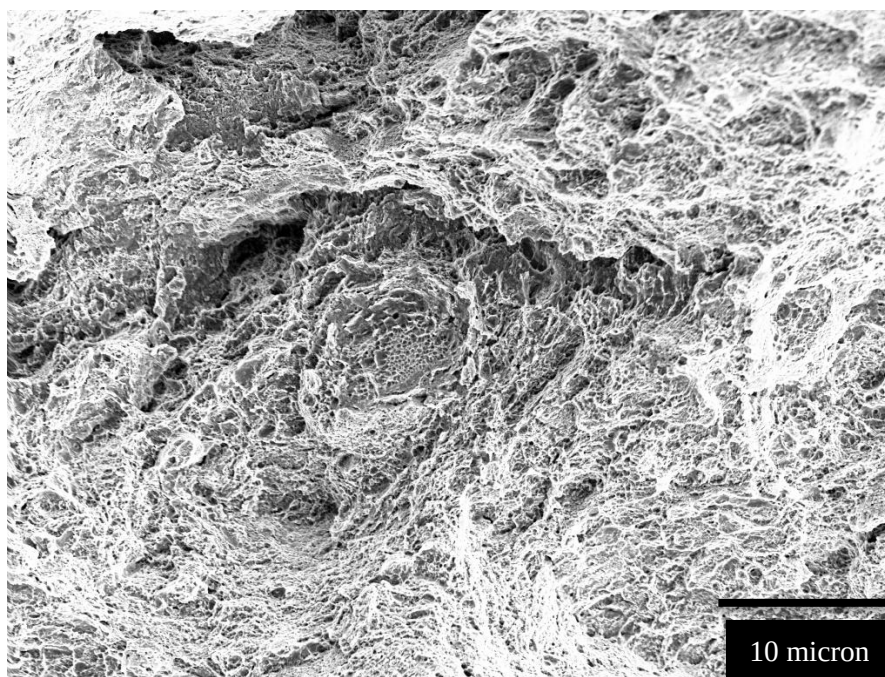


Figure 7 Shallow planar dimple feature