

NATIONAL TRANSPORTATION SAFETY BOARD

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

March 22, 2021



MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-013

1. ACCIDENT INFORMATION

Place : St. Agatha, Maine
Date : August 5, 2020
Vehicle : Piper PA-28-180, N7213W
NTSB No. : ERA20LA277
Investigator : Adam Gerhardt, AS-ERA

2. COMPONENTS EXAMINED

Crankshaft drive gear
Bolt
Lock plate remnant
Dowel remnant

3. DETAILS OF THE EXAMINATION

On August 5, 2020, about 1245 eastern daylight time, a Piper PA-28-180 airplane was substantially damaged when it was involved in an accident near St. Agatha, ME. The flight instructor and student pilot sustained minor injuries. According to the instructor, during flight the engine was unable to maintain normal airspeed and altitude at higher throttle inputs. The instructor identified an open field and completed a forced landing. During the landing roll through rough terrain, the airplane's landing gear collapsed, resulting in substantial damage to the fuselage. The airplane was retained for further investigation and several engine components were recovered and sent to the NTSB Materials Laboratory for additional examination.

Figure 1 shows the parts from the Lycoming O-360 engine, as received.¹ These parts, from the aft position of the crankshaft, included a crankshaft drive gear, attachment bolt, lock plate, and a fractured dowel remnant.

Figure 2 shows the drive gear from the aft and forward faces, as received. The drive gear had affixed to the aft face of the crankshaft via the lock plate and the attachment bolt. The aft face of the drive gear, shown in Figure 2a, exhibited the following vibroetched

¹ The O-360 is a family of four-cylinder, direct-drive, horizontally opposed, air-cooled, piston aircraft engines, manufactured by Lycoming Engines, headquartered in Williamsport, PA.

markings: "SN: 2203 13519548". The aft face did not exhibit any indications of plastic deformation or impact damage, although it did exhibit some darker areas consistent with carbonaceous deposits.

The forward face, shown in Figure 2b, exhibited some rotational scratch marks on the outer areas. As such, it exhibited a shinier, lighter color than the recessed central regions. This area though, did exhibit some radial witness marks. In the upper left of Figure 2b was the dowel hole. There were some circular wear marks surrounding the hole, with some rounding on the forward edge.

Figure 3 shows a typical view of some of the gear teeth. This figure demonstrates the contact areas on the faces of many of the drive gear teeth. The faces of the gear teeth exhibited some longitudinal wear marks and rectangular reflective regions, consistent with contact with the teeth of the mating gear. None of this wear was severe enough to manifest as gouging, deformation, or material loss on the gear, and was consistent with typical contact between gear teeth.

Figure 4 shows the attachment bolt from the side and the head. The head exhibited the markings "CP". The threaded areas of the bolt exhibited a consistent color and luster along all of the threads, and there was no indications of missing material, plastic deformation, or wear. The unthreaded portion of the shaft underneath the head side exhibited an area of chatter marks, consistent with fretting wear. No other damage was noted on the bolt.

Figure 5 shows a closer view of the threads from the bolt. The threads exhibited some rounding of the crests and wear on the threads of the lands. There were no indications of any purple, blue, red, or green substances that would be consistent with an applied thread-locking fluid.

Figure 6 shows the lock plate from the aft face, as received. The face edge opposite the U-shaped tab had been deformed aft ward. While most of the surfaces exhibited a light brown color consistent with oil exposure, the central portions of this face exhibited a ring of rotational wear, which exhibited circular witness marks and a lighter, more reflective luster. Further, the outer edges of the tab exhibited some lateral wear, exemplified by the witness marks and lighter color.

Figure 7 shows the fractured crankshaft dowel remnant, viewed from the side. As shown in the figure, the dowel exhibited longitudinal gouging and chatter marks, with areas of missing material, consistent with spalling. The forward area exhibited a fracture surface, which was oriented generally perpendicular to the longitudinal direction of the part.

The fracture surface of the dowel remnant is shown in Figure 8 and annotated to illustrate the different areas of interest in Figure 9. The fracture surface exhibited banded crack arrest marks, consistent with crack propagation, and ratchet marks, consistent with multiple crack initiation sites. These features were determined to be consistent with fatigue crack propagation, as detailed below. As demonstrated in Figure 9, the fracture surface

exhibited two opposite-facing fatigue cracks, whose features were consistent with having initiated at the dowel surface and propagating inward. A thin middle region exhibited different features, later determined to be consistent with subsequent overstress fracture.

The dowel remnant fracture surface was cleaned using acetone and examined using a scanning electron microscope (SEM). As shown in Figure 10 through Figure 12, the progressive regions of the fracture surface exhibited fatigue striations, consistent with fatigue crack propagation. On the larger crack, there was a large ratchet mark separating two areas of convex-shaped arrest marks (Figure 10). These features were consistent with two areas of crack propagation that advanced side-by-side. The fatigue striations increased in size towards the end of the crack (compare Figure 12 with Figure 11). Outside of the larger fatigue crack, dimpled rupture was observed (Figure 13). These features were consistent with subsequent overstress of the remnant cross section material.

The two areas of fatigue crack initiation along the dowel surface of the larger crack themselves exhibited smaller ratchet marks consistent with additional crack initiation sites (see Figure 14 and Figure 15). The primary fatigue crack initiation site is highlighted in Figure 16. This area exhibited radial marks emanating from the site along the surface. The site itself exhibited a rounded facet morphology, consistent with mechanical damage from impact. Figure 17 exhibits another crack initiation site near the one in Figure 16, which had been less damaged. This crack initiation site did not exhibit any mechanical or material fracture features.

The large crack primary crack initiation sites from Figure 16 are shown at an angle in Figure 18. This figure shows the impact damage to the crack initiation site. In addition, the site was located along an area of circumferential wear. The worn area exhibited a recessed morphology, with streaks of varying depths. Figure 19 shows a less damaged fatigue crack initiation site viewed from an angle. This location shows radial marks and crack arrest marks emanating from the worn surface.

As shown in Figure 8 and Figure 9, the dowel fracture surface exhibited a second, smaller progressive crack, facing opposite the larger fatigue crack. Part of this smaller crack face is shown in Figure 20. This area exhibited fatigue striations, consistent with fatigue crack propagation with ratchet marks, consistent with multiple fatigue crack initiation sites. One of those crack initiation sites is shown in Figure 21. This site, as well as many of the other, exhibited smearing, consistent with post-fracture or post-cracking impact damage.

The observed features from the fractured dowel remnant were consistent with reverse bending fatigue. This bending led to crack initiation along worn regions of the dowel exterior at multiple locations. These smaller cracks eventually coalesced and propagated inward, eventually from opposite sides. Once the fatigue cracks had propagated far enough inward, the remaining cross section of the dowel succumbed to overstress fracture.

The chemical composition of the dowel remnant was examined using energy dispersive x-ray spectroscopy (EDS). From the data obtained using these techniques, the remnant was found to be consistent with an alloy steel, such as Type 4340.

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Materials Research Engineer



Figure 1 – View of the crankshaft drive gear, bolt, lockplate, and fractured pin, as received.

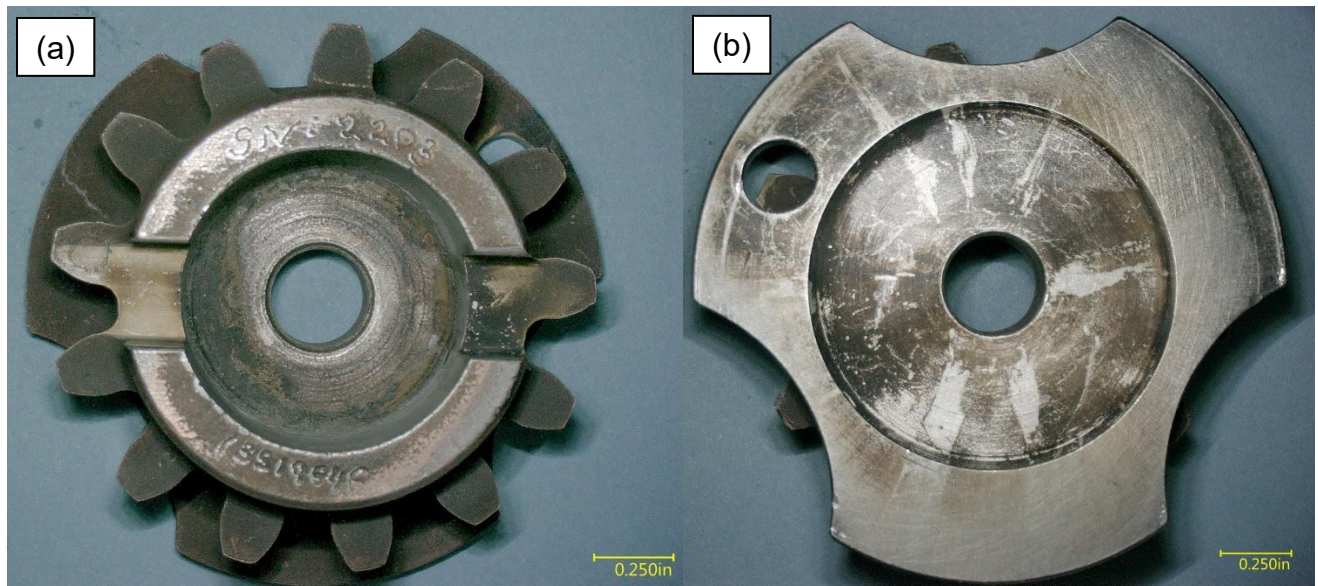


Figure 2 – The drive gear viewed from the (a) aft side and (b) the forward side, as received.

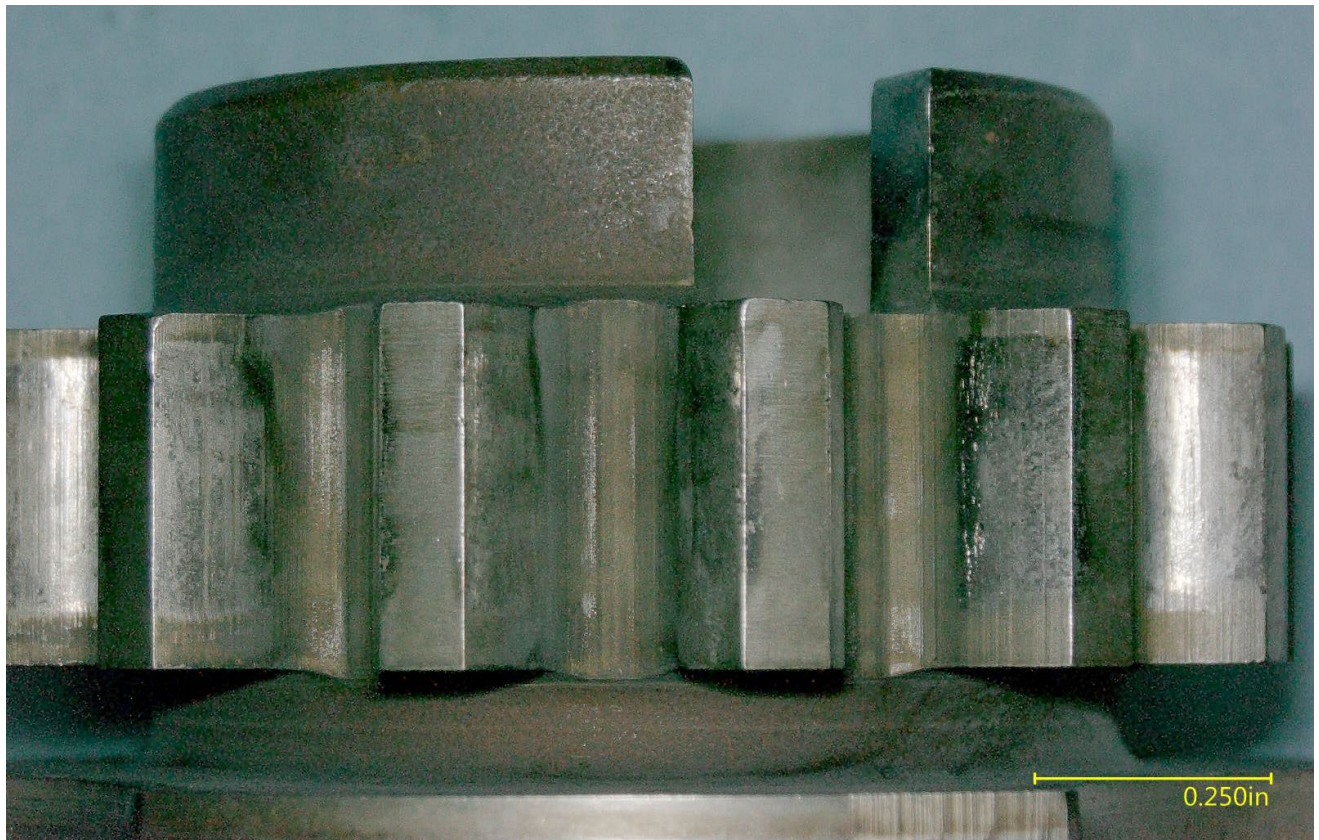


Figure 3 – Closer view of the drive gear teeth surfaces, as received.

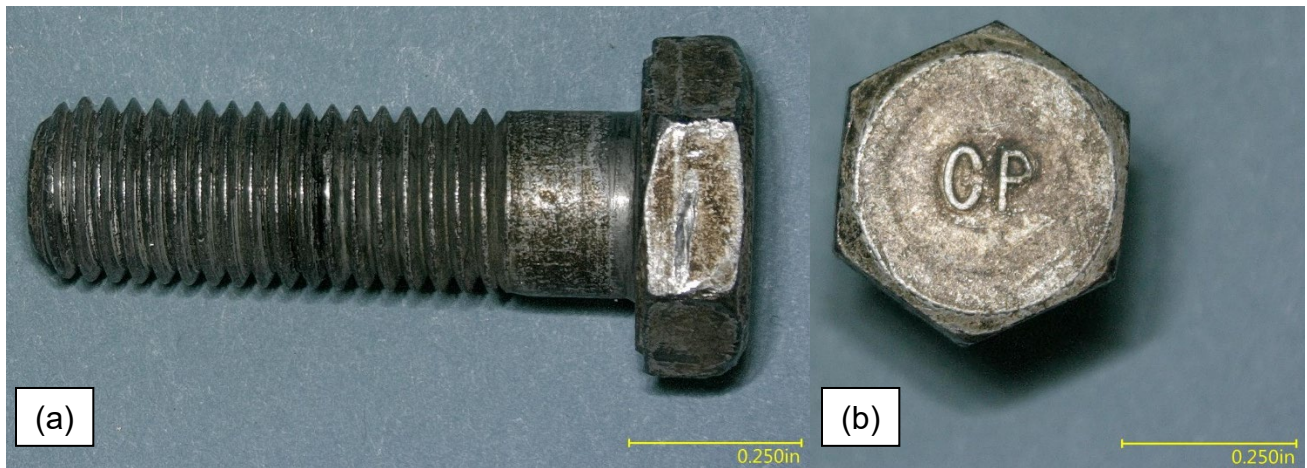


Figure 4 – The attachment bolt, viewed from (a) the side with the threads and (b) the head.



Figure 5 – Closer view of the threads of the attachment bolt.



Figure 6 – The lock plate, viewed from the aft side, as received.



Figure 7 – View of the fractured crankshaft dowel from the side.



Figure 8 – View of the fracture surface of the dowel remnant.

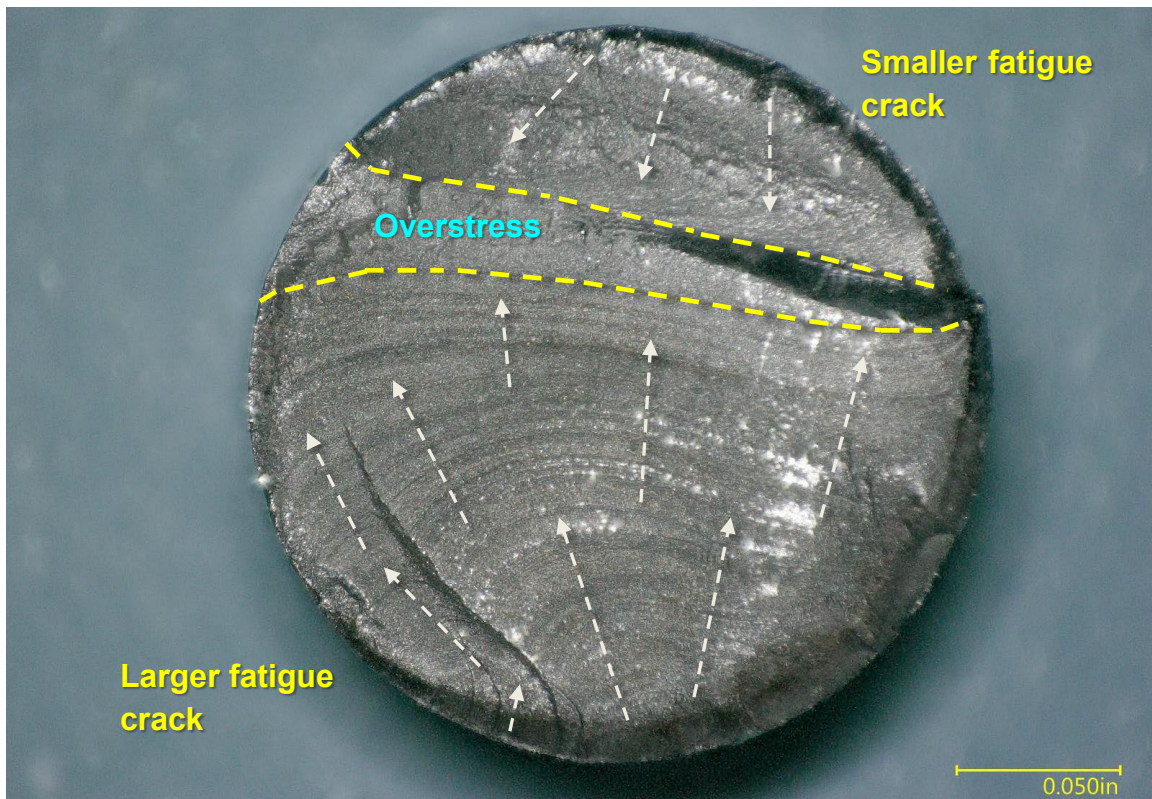


Figure 9 – Annotated view of Figure 8, showing different fracture areas.

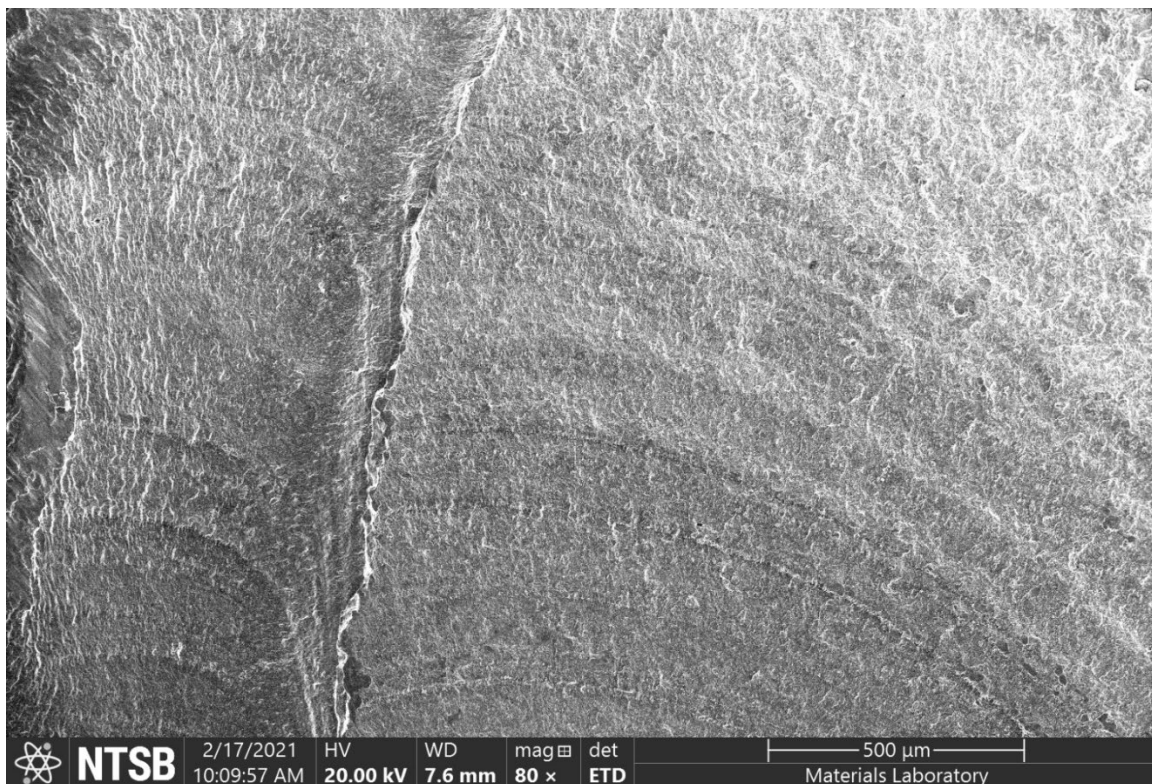


Figure 10 – Secondary electron (SE) micrograph of bow-shaped fatigue striations on two cracks separated by a ratchet mark.

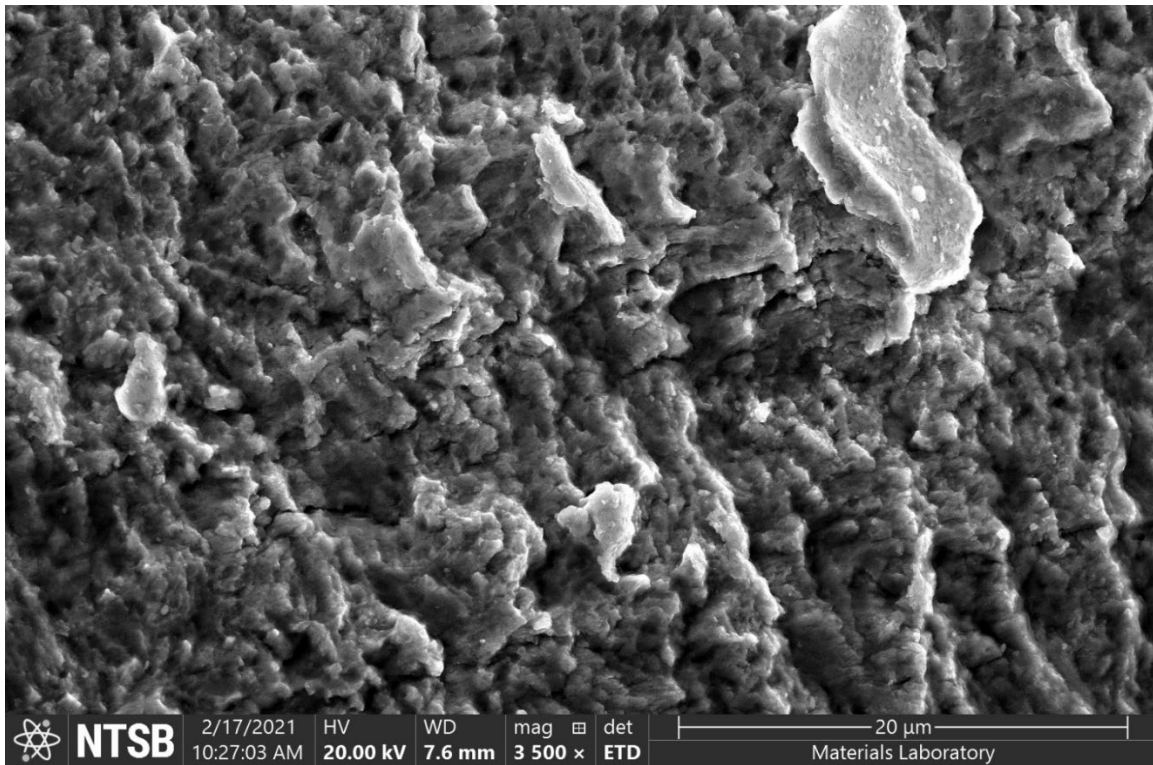


Figure 11 – SE micrograph of a closer view of the fatigue striations in Figure 10.

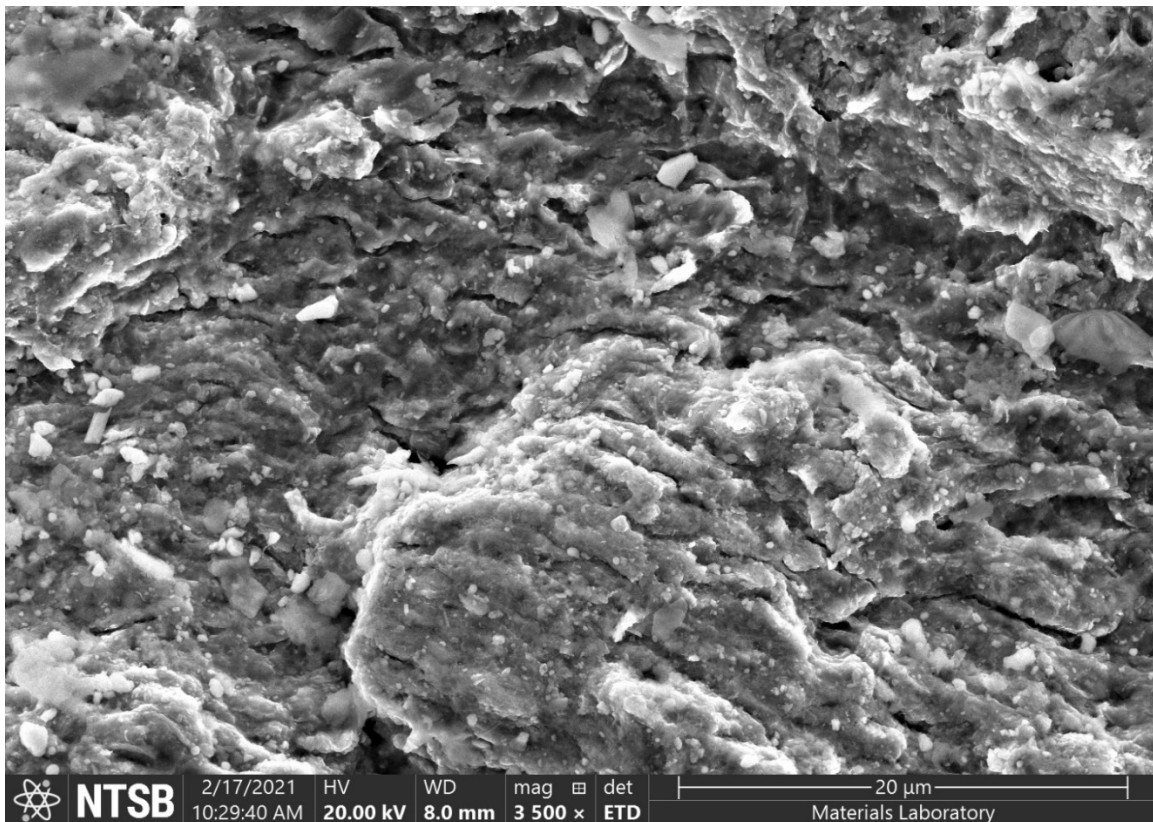


Figure 12 – SE micrograph of fatigue striations at the end of the large crack front.

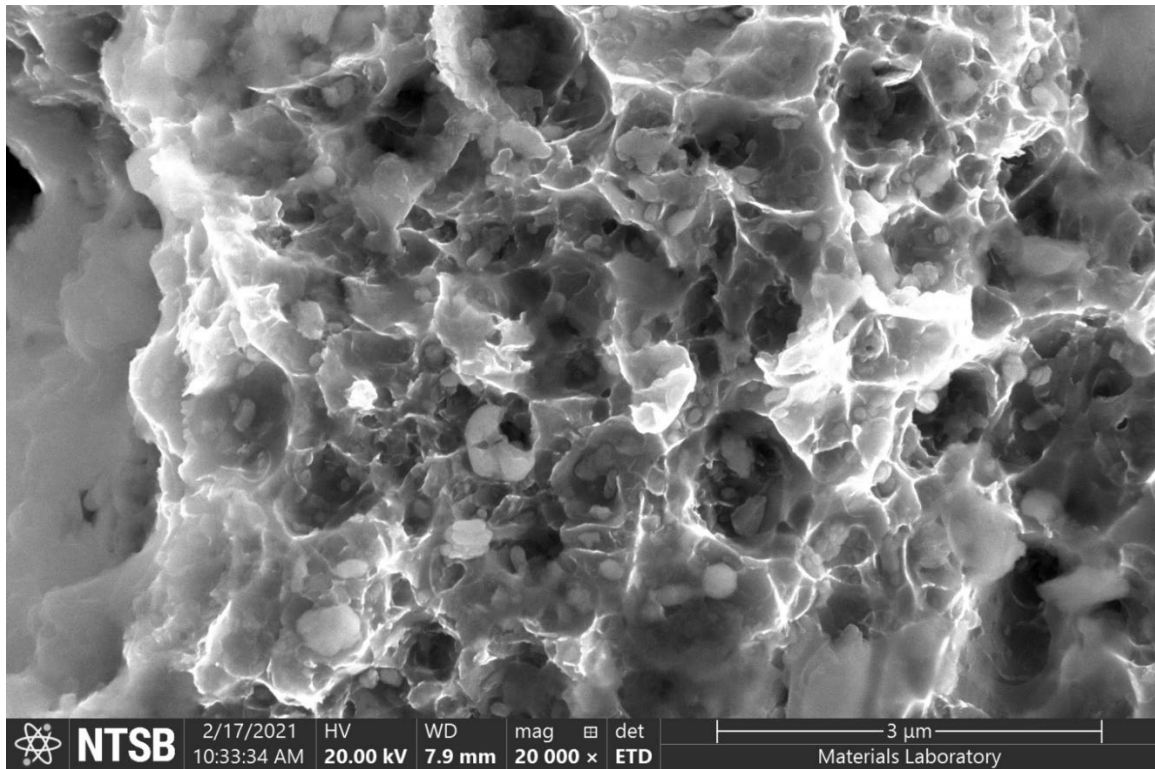


Figure 13 – SE micrograph of dimpled rupture in the overstress area of the dowel.

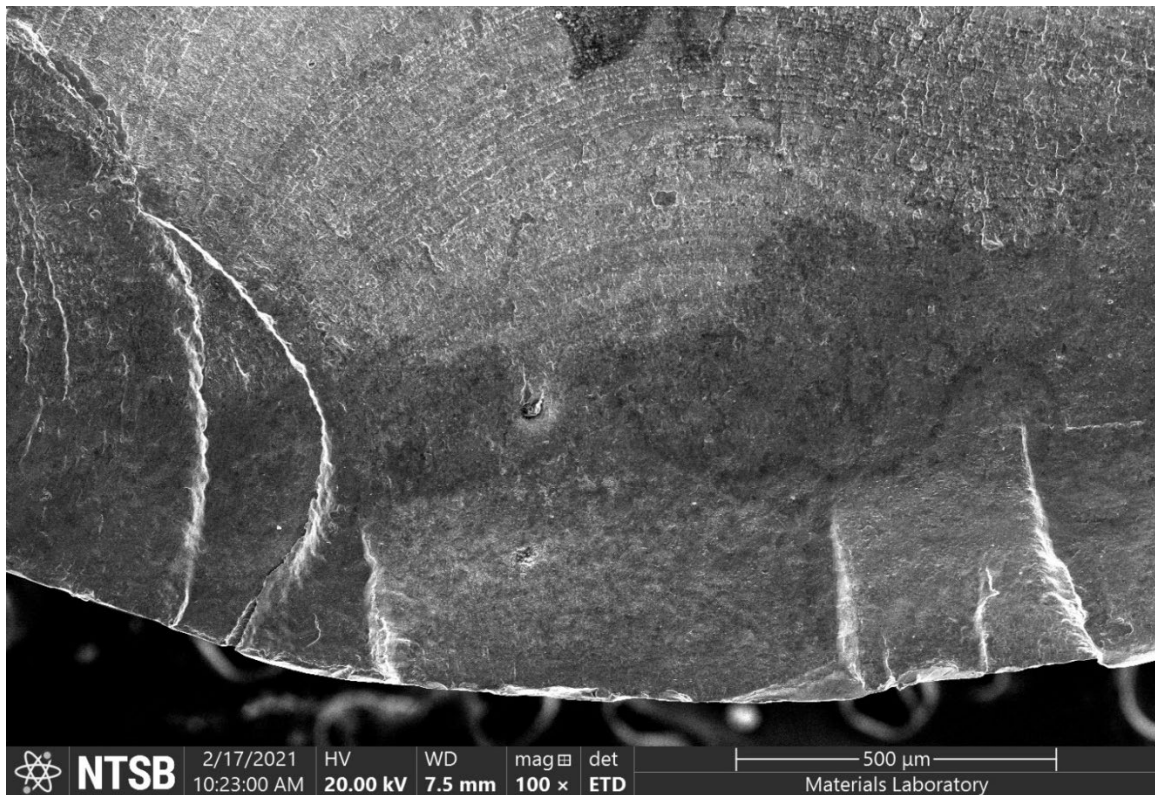


Figure 14 – SE micrograph of the primary fatigue crack initiation sites.

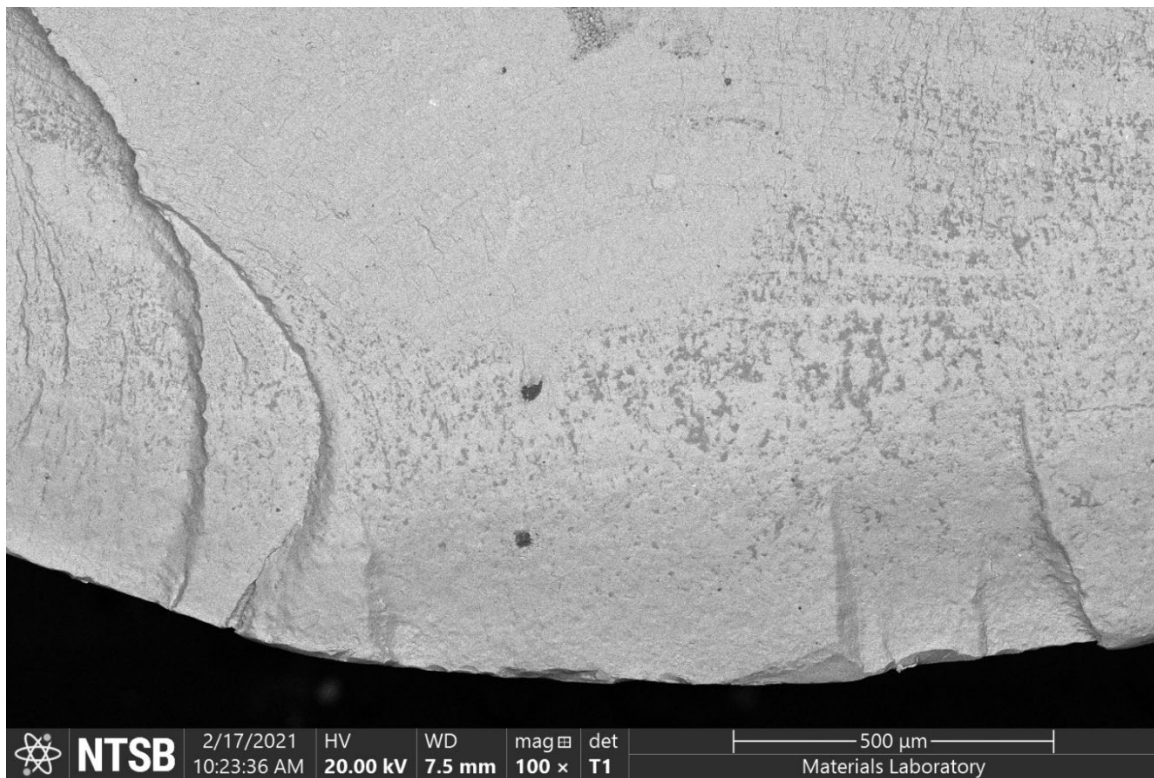


Figure 15 – Backscattered electron (BE) micrograph of the initiation sites in Figure 14.

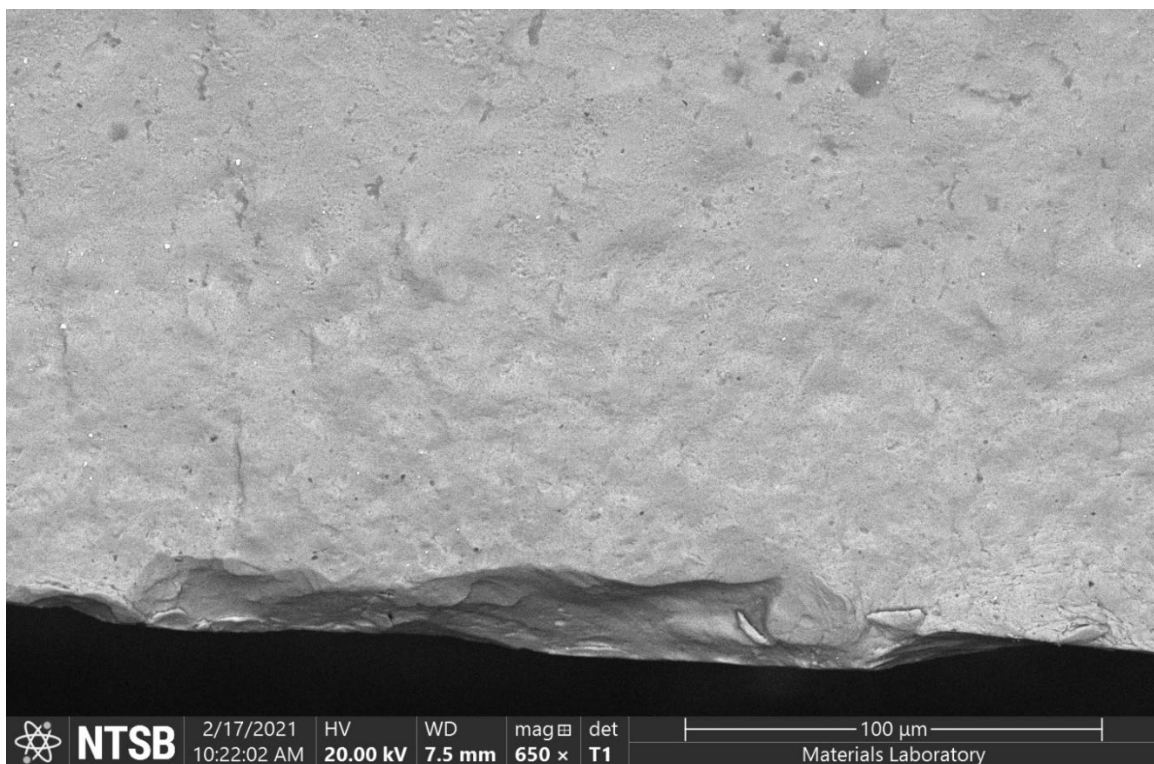


Figure 16 – BE micrograph of the main fatigue crack initiation site, showing mechanical damage.

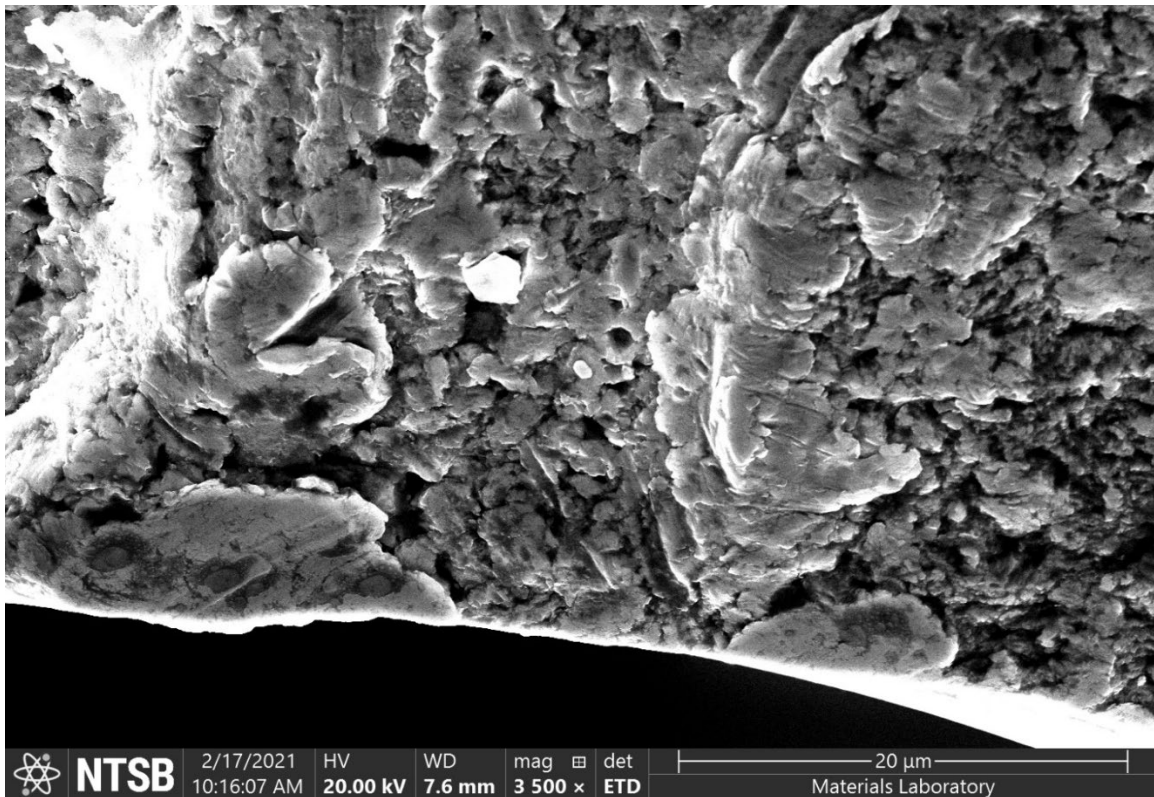


Figure 17 – SE micrograph of another crack initiation site away from Figure 16.

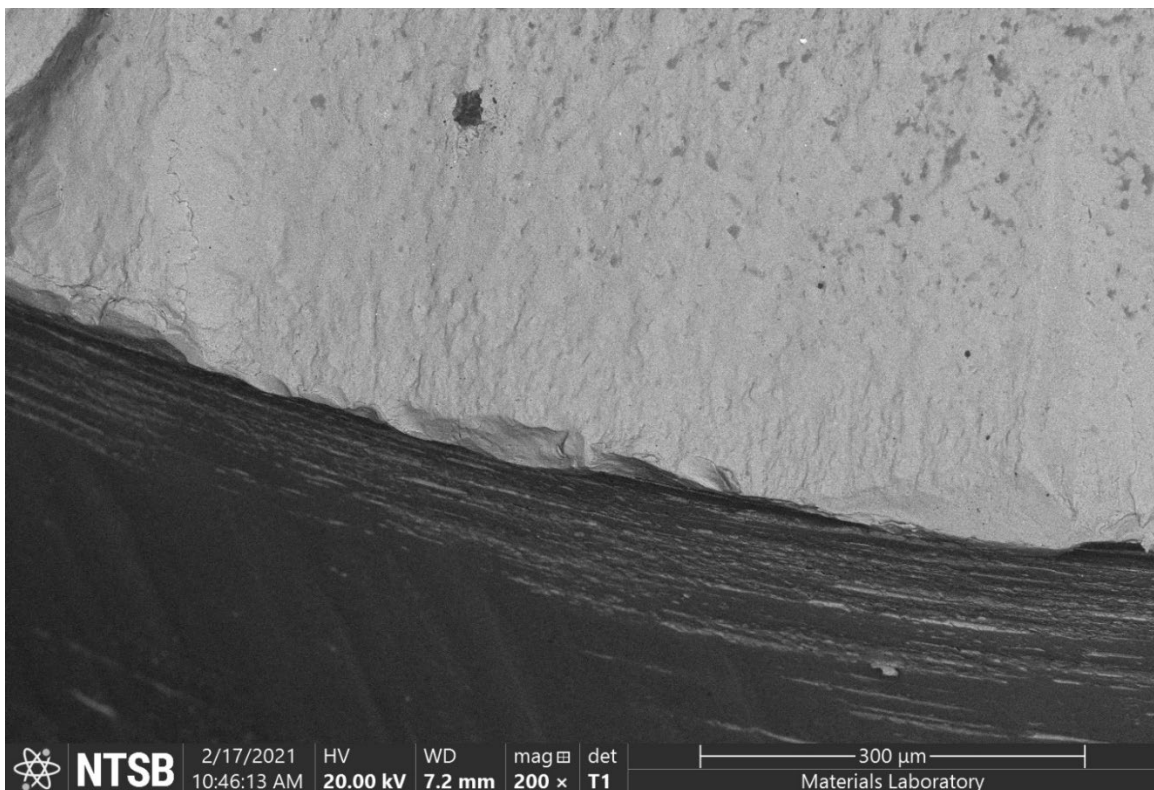


Figure 18 – BE micrograph of the initiation site in Figure 16, shown at an angle.

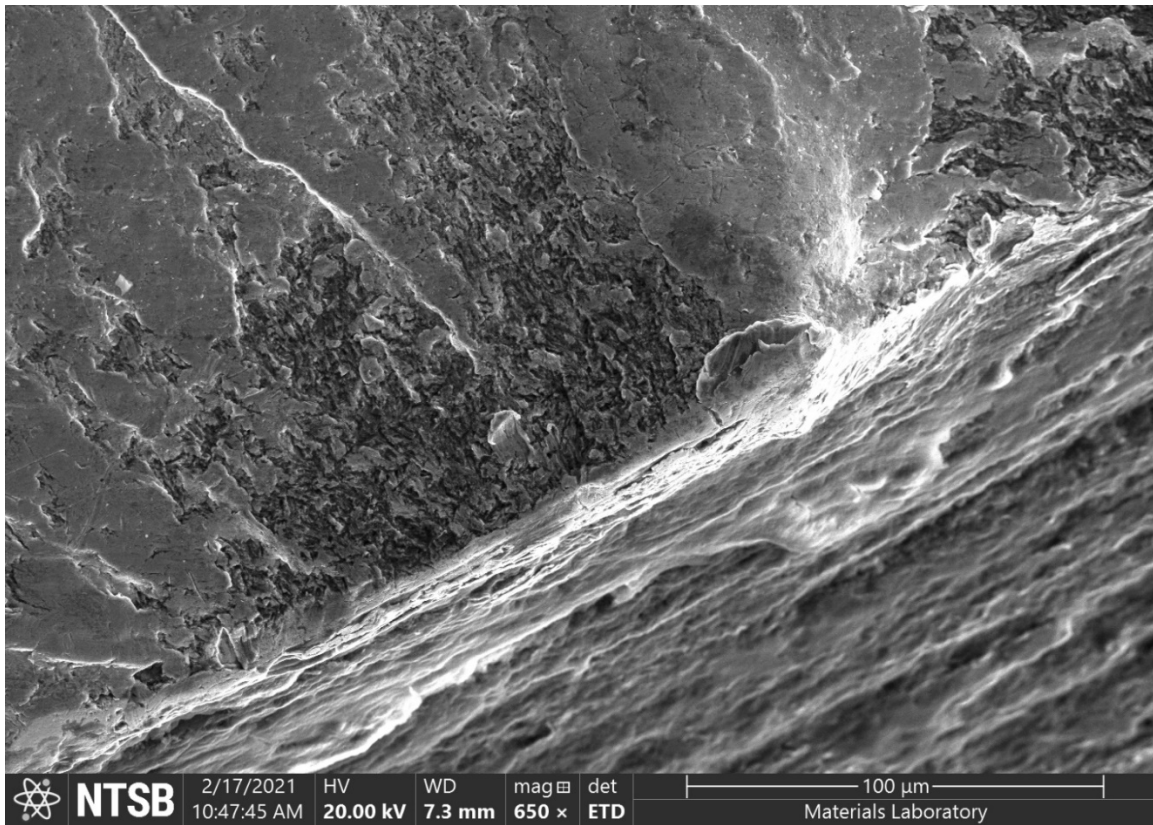


Figure 19 – SE micrograph of an angled view of an undamaged initiation site.

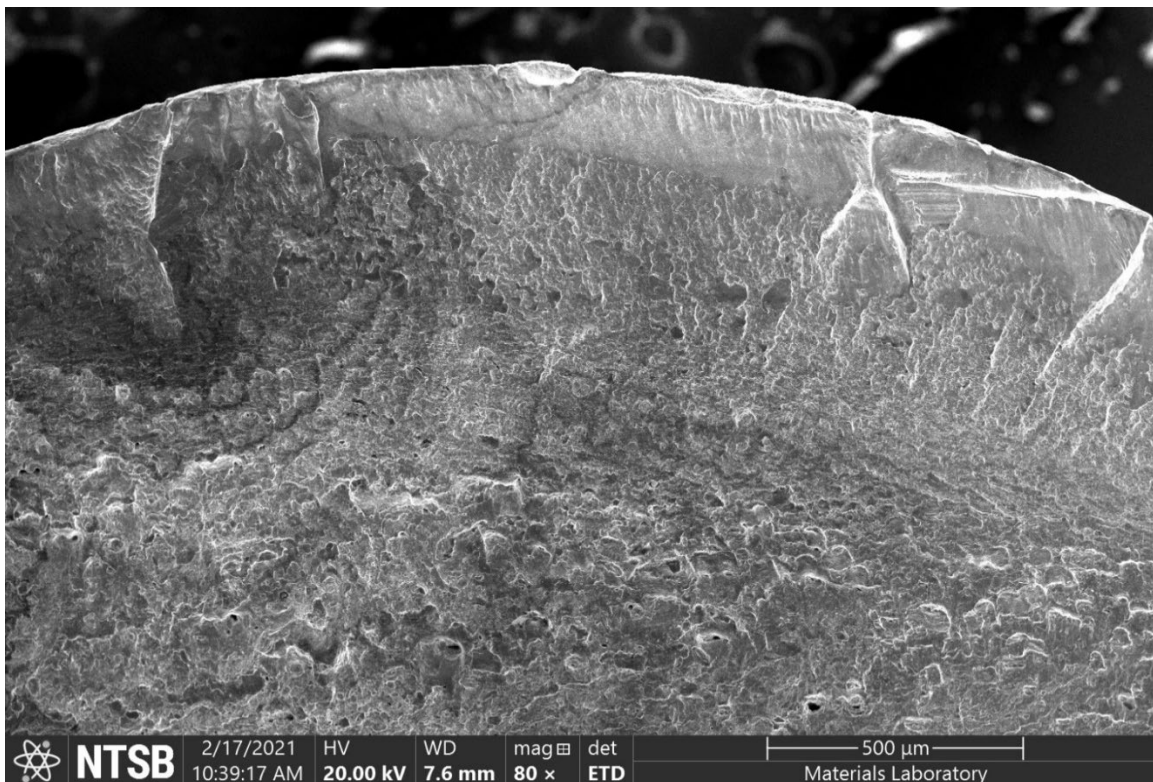


Figure 20 – SE micrograph of the smaller opposite-facing fatigue crack.

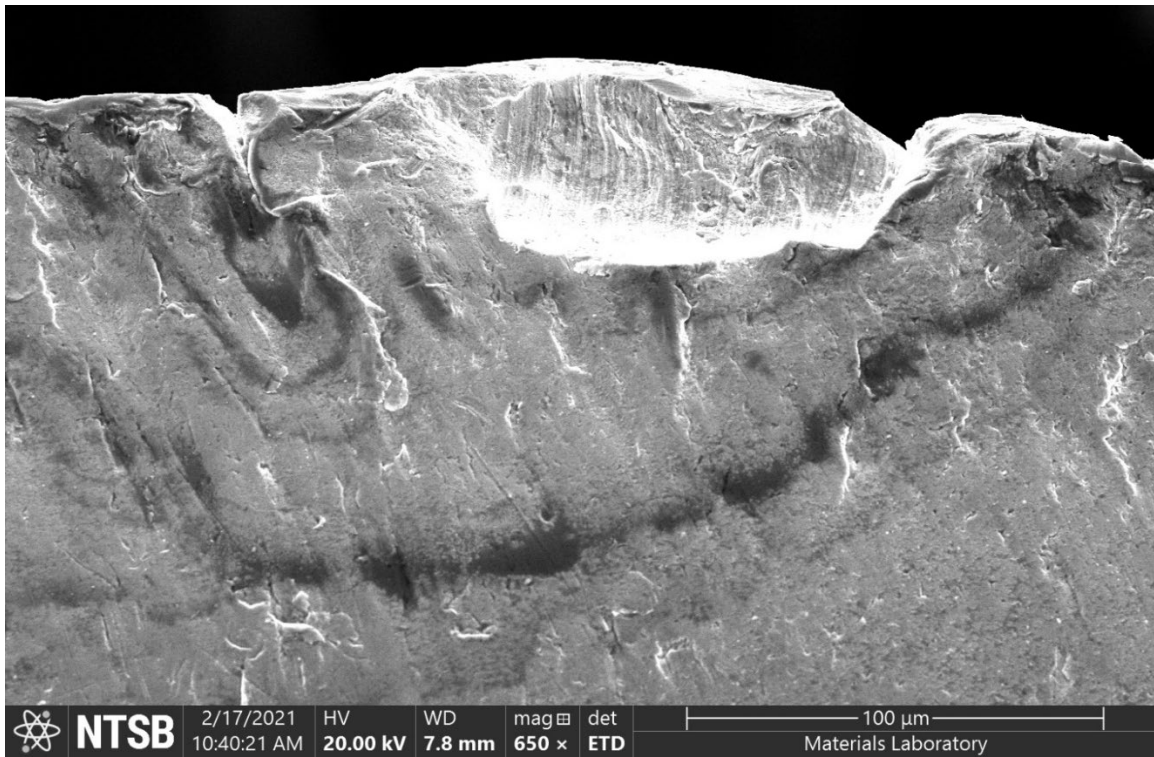


Figure 21 – SE micrograph of one of the fatigue crack initiation sites of the smaller fatigue crack.