

NATIONAL TRANSPORTATION SAFETY BOARD

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

February 19, 2021



MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-002

1. ACCIDENT INFORMATION

Place : Hemet, California
Date : April 30, 2020
Vehicle : Piper PA-23-250, N6521Y
NTSB No. : WPR20LA135
Investigator : Fabian Salazar, AS-WPR

2. COMPONENTS EXAMINED

Remnants of a propeller mounting flange
Remnants of a control cable

3. DETAILS OF THE EXAMINATION

On April 30, 2020, about 1230 Pacific daylight time, a Piper PA-23-250 airplane was substantially damaged when it was involved in an accident near Hemet, CA. The pilot was fatally injured. According to a second pilot, employed by the same company, he and the accident pilot were conducting aerial survey work over selected areas of land around the city of Palm Springs, CA in two airplanes. The second pilot reported hearing a distress call during the flights. The second pilot reported that he observed the accident airplane descending rapidly.

Examination of the accident site revealed that the airplane impacted steep mountainous terrain and came to rest inverted about 15 miles west of the intended aerial survey area. The debris path was about 300 ft. in length, oriented on a heading of about 270°. One propeller was unaccounted for. All other major structural components of the airplane were located within the debris path. The wreckage was recovered to a secure location for further examination.

Figure 1 shows the remnant of the propeller mounting flange, as received. The flange remnant had been sectioned close to the flange (as shown in Figure 1b), and it exhibited a circular fracture surface on the opposite side, as shown in Figure 1a. Figure 2 shows the flange remnant viewed from an angle. The sides of the remnant consisted of two parallel circular flanges with a groove for a cable.

The fracture surface exhibited an angled orientation, as illustrated in Figure 2. The river patterns exhibited a rotational quality, consistent with the fracture surface orientation. There was a small ridge or lip (seen in the upper left of Figures 1a and 2). The fracture surface was rough in texture, with a dull, fibrous appearance. These features were consistent with fracture from torsional overstress.

A portion of the remnant fracture surface was examined using a scanning electron microscope (SEM). As seen in Figure 3, much of the fracture surface exhibited smoothed and streaky features consistent with smearing, a form of post-fracture damage. Closer examination of the undamaged regions of the pulley fracture surface, such as typified in Figure 4, revealed dimpled rupture, consistent with overstress fracture. There were no other indications of other fracture modes on this fracture surface. These features were consistent with fracture of the flange in torsional overstress.

Figure 5 shows the remnant of the control cable, as received. The control cable measured approximately 123 inches (10.25 ft.) long. As shown in the upper right of Figure 5, and highlighted in Figure 6 and 7, the cable had fractured on one end. The cable consisted of six strands of wires wrapped about a central core strand. All the strands had fractured in approximately the same location, perpendicular to the cable direction. In looking at Figure 7, two of the strands exhibited little fraying of the wires, whereas the other four exhibited local fraying upwards of 0.5 inch from the fracture surfaces. The core strand exhibited fraying several inches from the fracture surface.

Figure 8 shows a montage of microscopic Z-stack photos of one of the frayed strands. The fractured wires showed several different fracture surface orientations. Most exhibited a slanted orientation, with some localized necking near the fracture. Others had necked and were completely rounded, consistent with some post-fracture damage. There were also three fractured wires with flat fracture surfaces oriented perpendicular to the wire direction.

Figure 9 and 10 show microscopic images of two other frayed strands. These wires were mostly necked or thinned near the fracture surface. Several others exhibited a flat fracture surface, along with an ovoid or oblong wire shape adjacent to the fracture. The wires that have frayed out the most from the main strand exhibited rounding absent a fracture surface—these wires were consistent with having undergone some post-fracture damage or wear after breaking.

Figure 11 shows a montage of two of the most intact or unfrayed wire strands. Like the other bundles, these exhibited wire fractures with angled or cup-shaped fractures, with thinning or necking near the fracture surfaces. Several of the wires located outward from the main strand had been rounded or worn to a flat point, consistent with post-fracture damage.

The two most damaged or frayed wire strands were inspected using a SEM, as shown in Figure 12. As observed visually, many of the fractured wires exhibited the features shown in Figure 13. This wire in this figure exhibited localized necking adjacent

to the fracture surface, with a general cup-shape morphology. Most of the fractured wires contained post-fracture contamination, which manifests as non-conductive noise when imaging using a SEM. A closer view of the undamaged, uncontaminated portions of the fracture surface of the wire in Figure 13 is shown in Figure 14. This wire exhibited dimpled rupture, which along with the cup and cone fracture morphology, was consistent with tensile overstress fracture of a ductile material.

Three of the fractured wires in Figure 12 exhibited an oblong or flattened shape at the fracture surface. One of these wires is highlighted in Figure 15. Much of the wire fracture surface had been damaged by smearing, consistent with post-fracture damage. However, the undamaged portion of the fractured wire exhibited crack arrest marks and ratchet marks, consistent with progressive crack propagation and multiple crack initiation sites, respectively. A closer view of the wire fracture surface revealed fatigue striations, consistent with fatigue crack propagation (see Figures 16 and 17). As demonstrated in Figure 18, the fatigue crack initiation sites on this wire had been obliterated by smearing.

Figure 19 shows a second oblong-shaped fractured wire. As demonstrated by the dark material in the figure, the left half of the fracture surface exhibited non-conductive surface contamination.¹ The right side of the wire fracture surface exhibited fatigue striations, as shown in Figure 20. Figure 21 shows a third wire exhibiting fatigue striations from the strand. This surface exhibited clear fatigue striations and crack arrest marks (see Figure 22).

Figure 23 shows several of the fractured wires from the second wire strand. As seen in the figure, many of these wires exhibited flat fracture surfaces. One such wire fracture is highlighted in Figure 24. This wire exhibited three distinct fracture regions—two which showed fatigue striations (as highlighted in Figure 25), and a middle one exhibiting dimpled rupture. These features were consistent with fracture of this wire by reverse-bending fatigue.

Figure 25 also shows some of the smaller fatigue crack initiation sites of the wire. These initiation sites exhibited some faceted features along the 10 μm closest to the surface. Each of these sites had a corresponding ratchet marks at the first 20 μm of the fatigue cracking on the fracture surface, consistent with these smaller fatigue cracks coalescing into a larger crack during propagation.

Figure 26 shows another fractured wire with fatigue striations on one half of the fracture. The other (upper) half of the fracture exhibited a rougher texture with dimpled rupture, consistent with subsequent overstress fracture. The portion of the wire along the overstress side also exhibited localized necking and cup-like features. These were consistent with a fatigue crack that had propagated approximate halfway through the wire cross section before the remainder succumbed to tensile overstress fracture.

¹ Backscattered electrons: SEM micrographs produced using backscattered electrons display contrast that is associated with the atomic numbers of the elements in the micrograph. Materials containing elements with higher atomic numbers visually appear lighter relative to other materials containing elements with lower atomic numbers.

Several of the wire strands were mounted, ground, and polished for cross-sectional metallurgical examination. As shown in Figure 23, a longitudinal section of one of the wires that fractured from fatigue exhibited elongated grain flow and structure (parallel to the drawing direction of the wire). The surfaces of the wires exhibited a coating.

The chemical composition of the sectioned wires was examined using energy dispersive x-ray spectroscopy (EDS). From the data obtained, the wires were found to be consistent with carbon steel that had been galvanized (zinc coated). The hardness of one of the wires was inspected per ASTM E384.² The hardness averaged 47 HRC (493 HV₅₀₀).

Erik M Mueller
Materials Research Engineer

² ASTM E18 – *Standard Test Method for Knoop and Vickers Hardness of Materials*. ASTM International, West Conshohocken, PA.

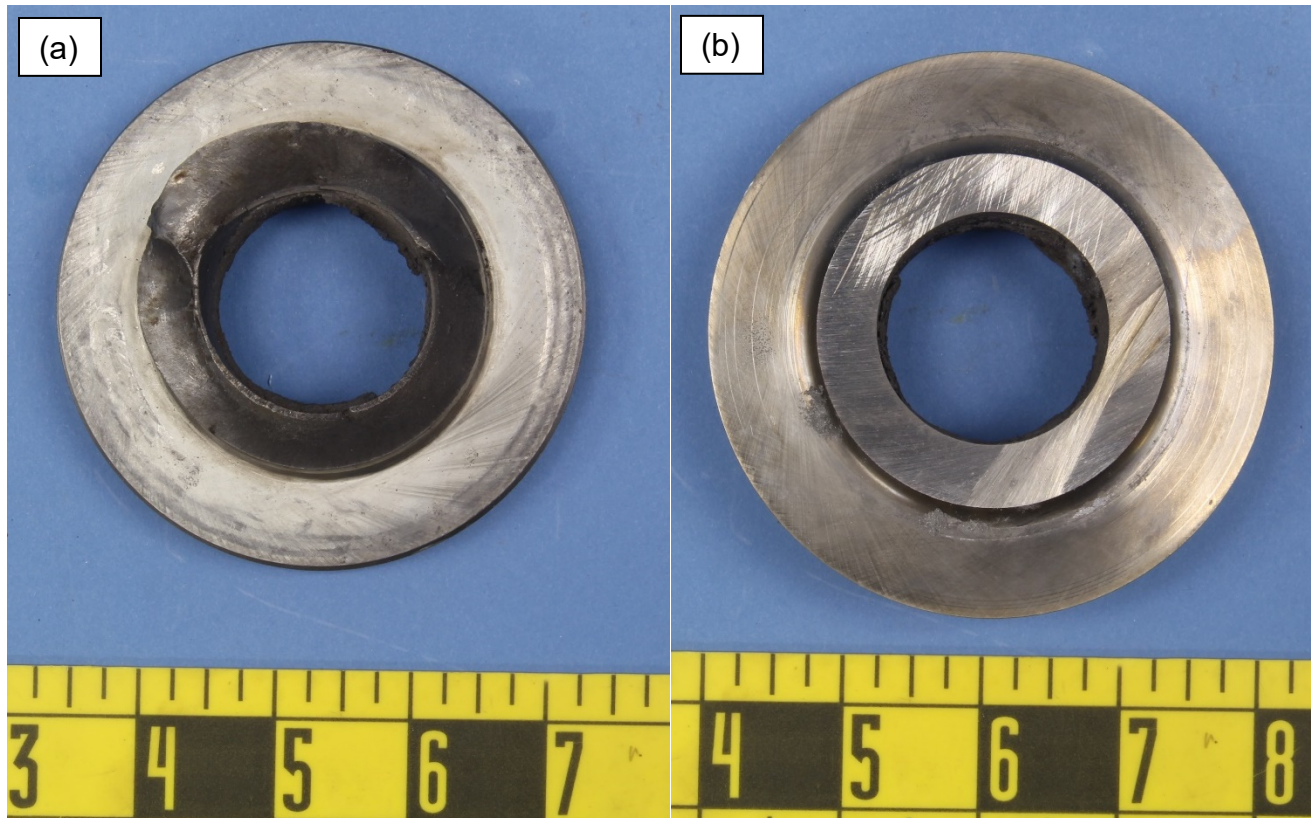


Figure 1 – Closer view of the propeller mounting flange, viewed from (a) the fractured side and (b) the reverse side.



Figure 2 – The flange remnant, viewed from an angle, showing the angled fracture surface.

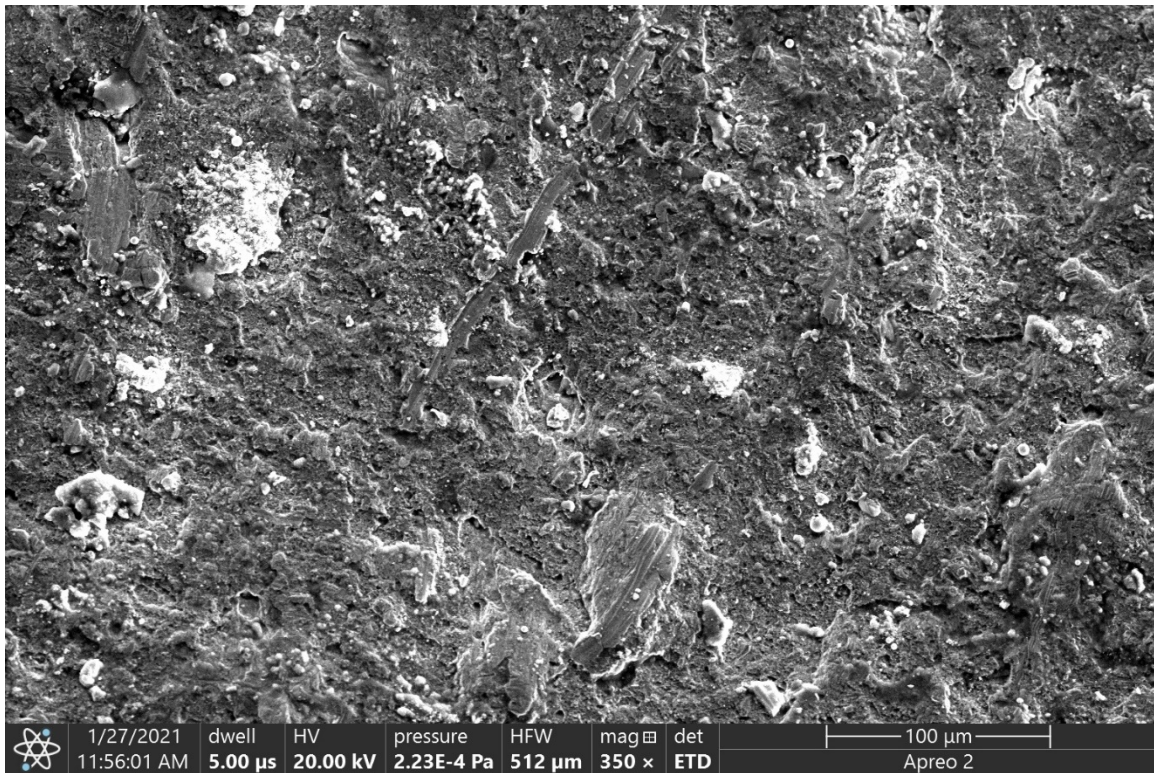


Figure 3 – Secondary electron (SE) micrograph of the remnant fracture surface, showing post-fracture damage and smearing.

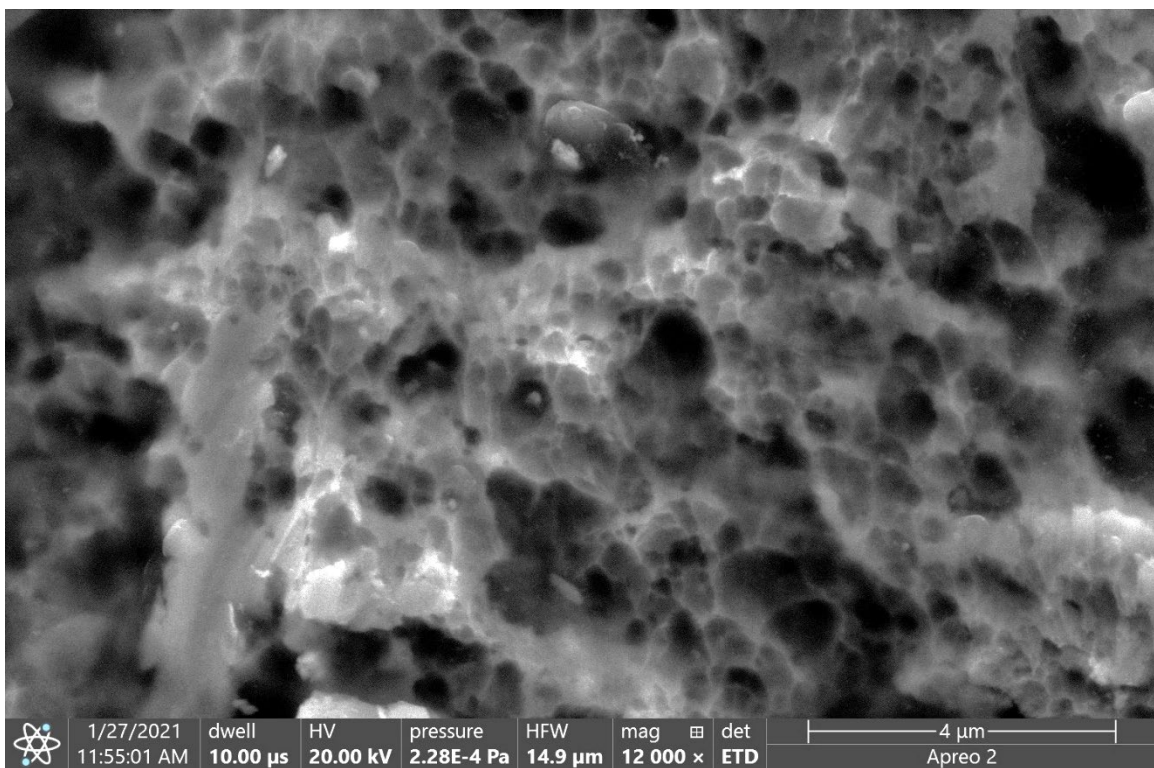


Figure 4 – SE micrograph of the remnant fracture surface, showing dimpled rupture.



Figure 5 – The control cable remnant, as received.

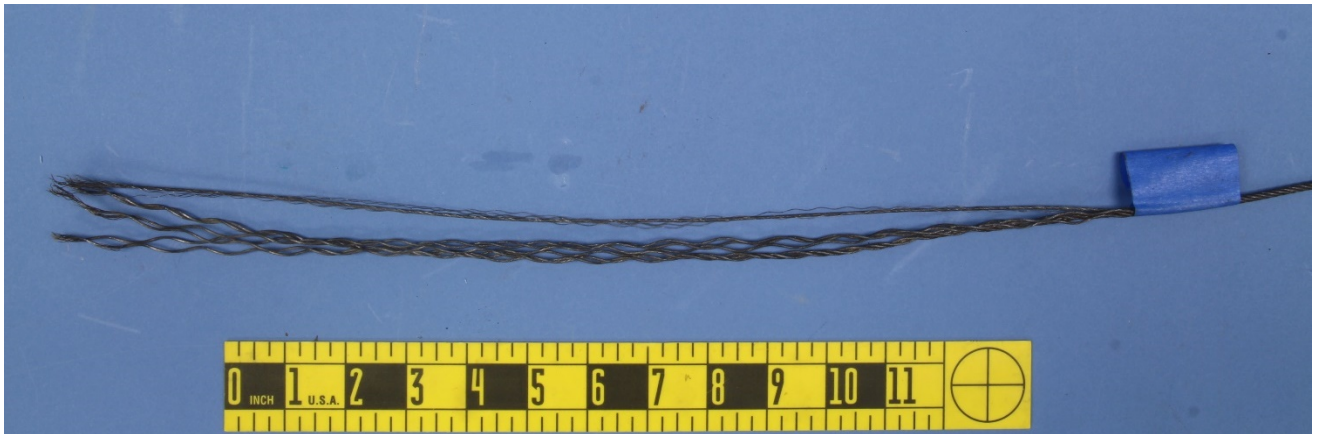


Figure 6 – View of the fractured end of the control cable remnant.



Figure 7 – View of the fractured control cable strands.



Figure 8 – View of some of the fractured wires from the frayed strand of the cable fracture.



Figure 9 – View of the second strand of frayed wires on the fractured cable.



Figure 10 – View of the third set of wire strands on the fractured cable.



Figure 11 – Montage view of the 4th and 5th wire strand sets from the fractured cable.

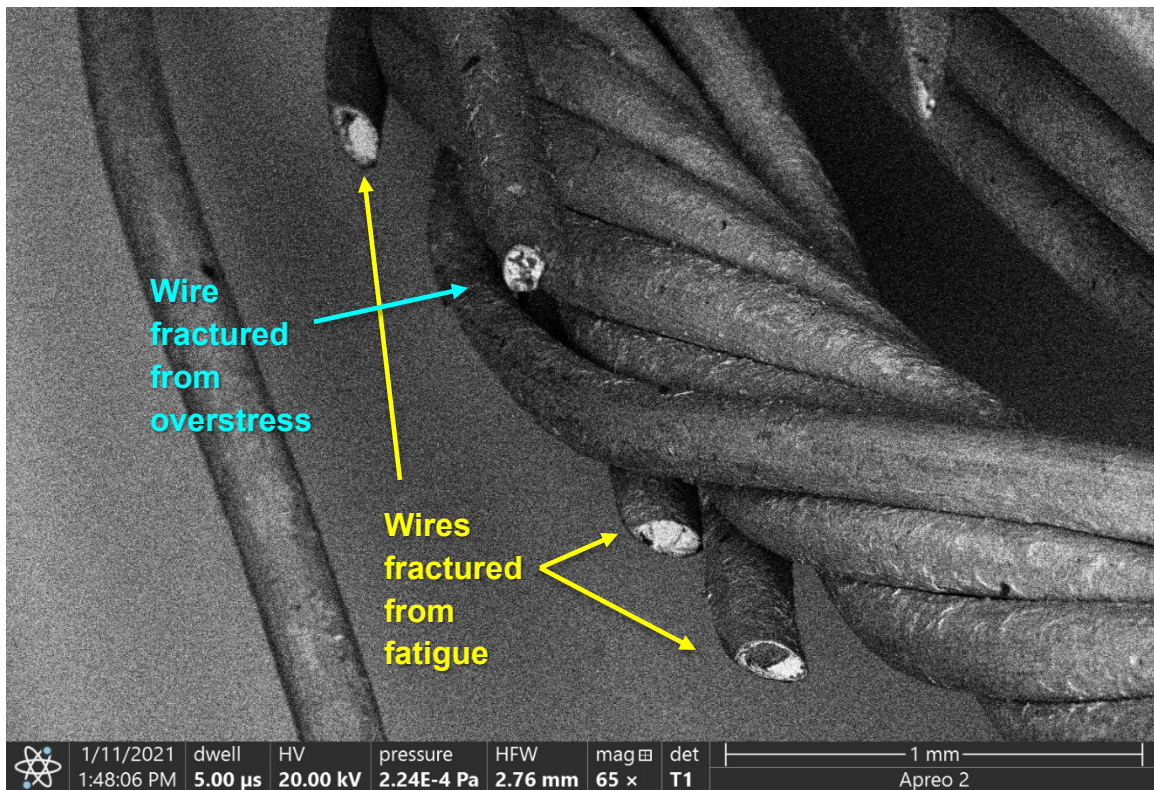


Figure 12 – Backscattered electron (BE) micrograph of one of the frayed, fractured wire strands.

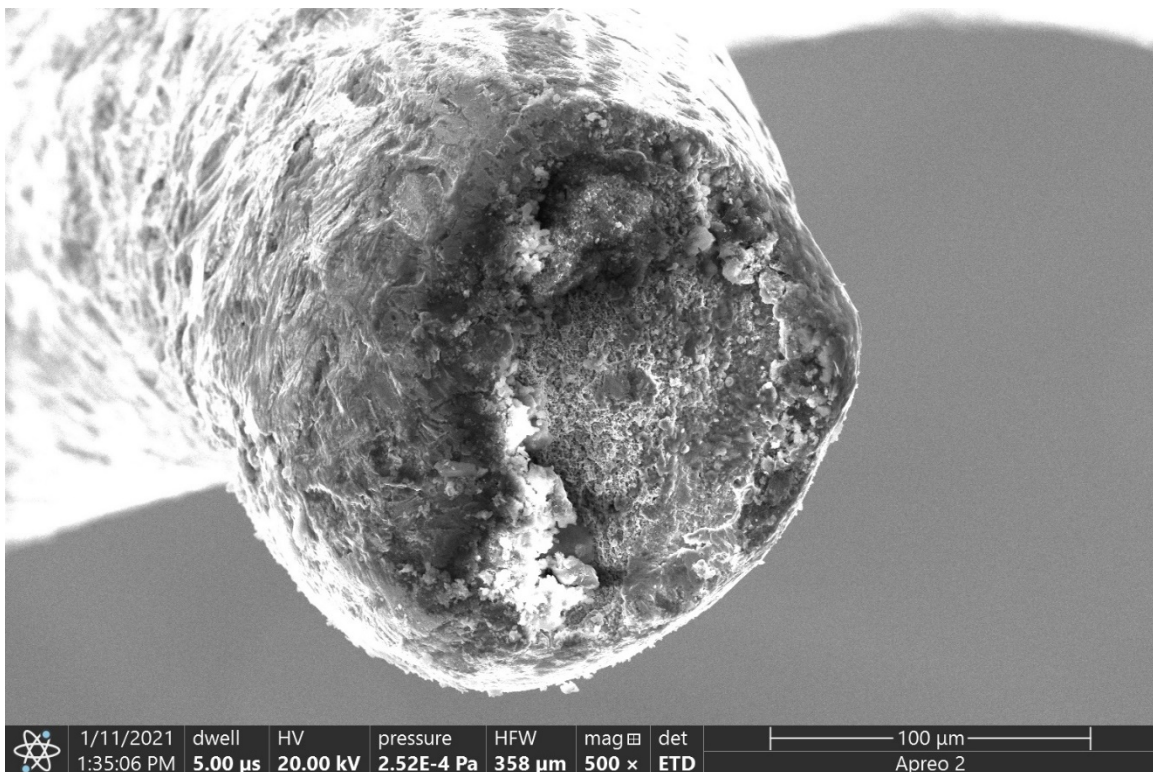


Figure 13 – Secondary electron (SE) micrograph of a fractured strand, showing necking.

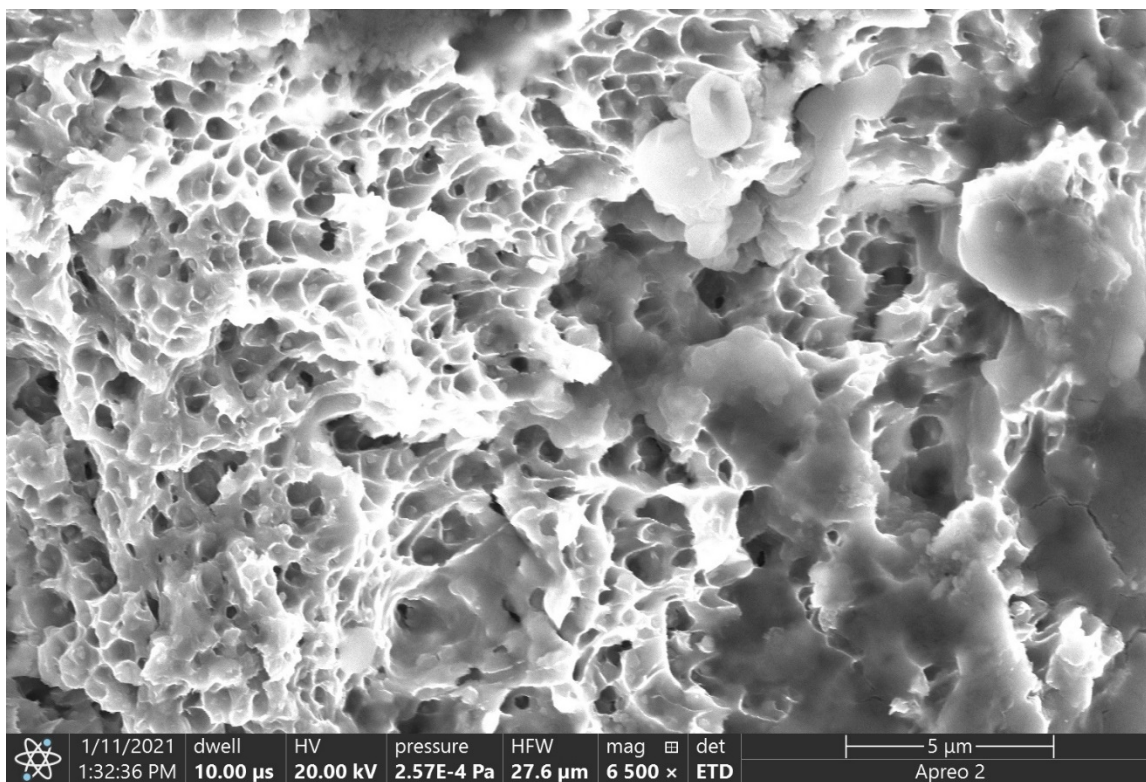


Figure 14 – SE micrograph showing dimple rupture from the fracture in Figure 13.

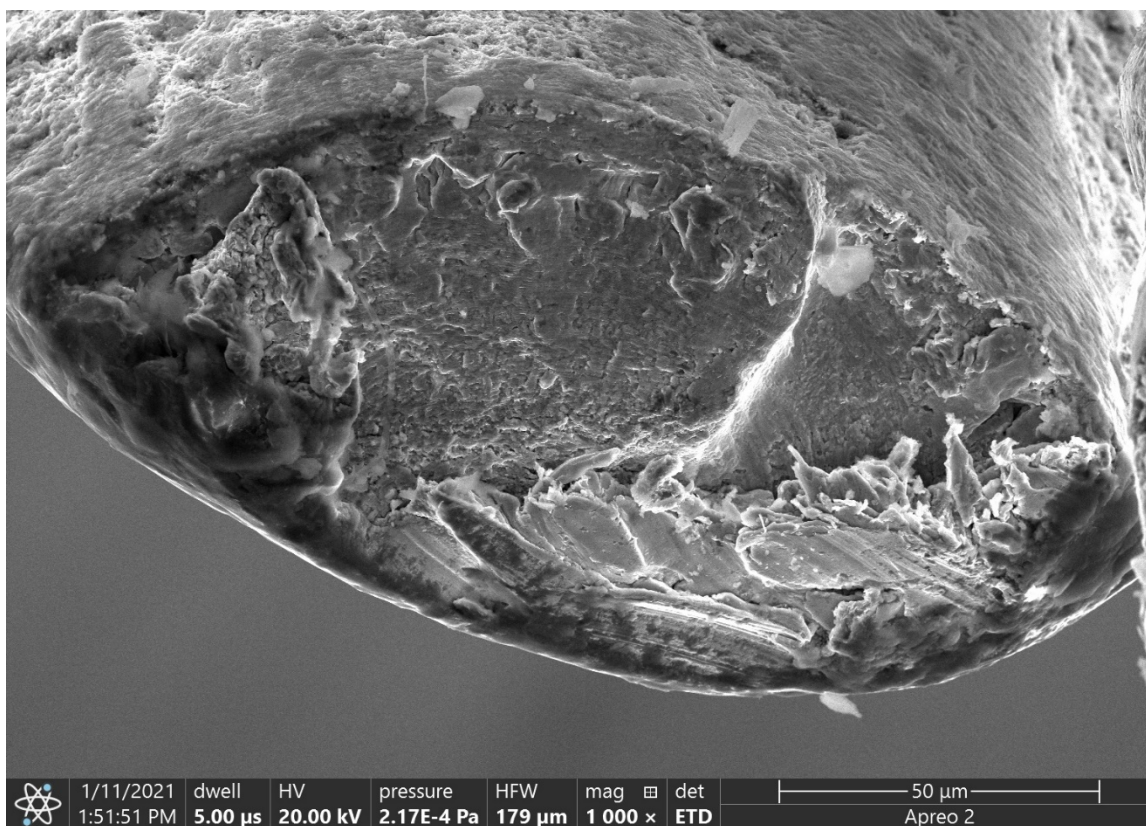


Figure 15 – SE micrograph of an oblong wire fracture, exhibiting fatigue features.

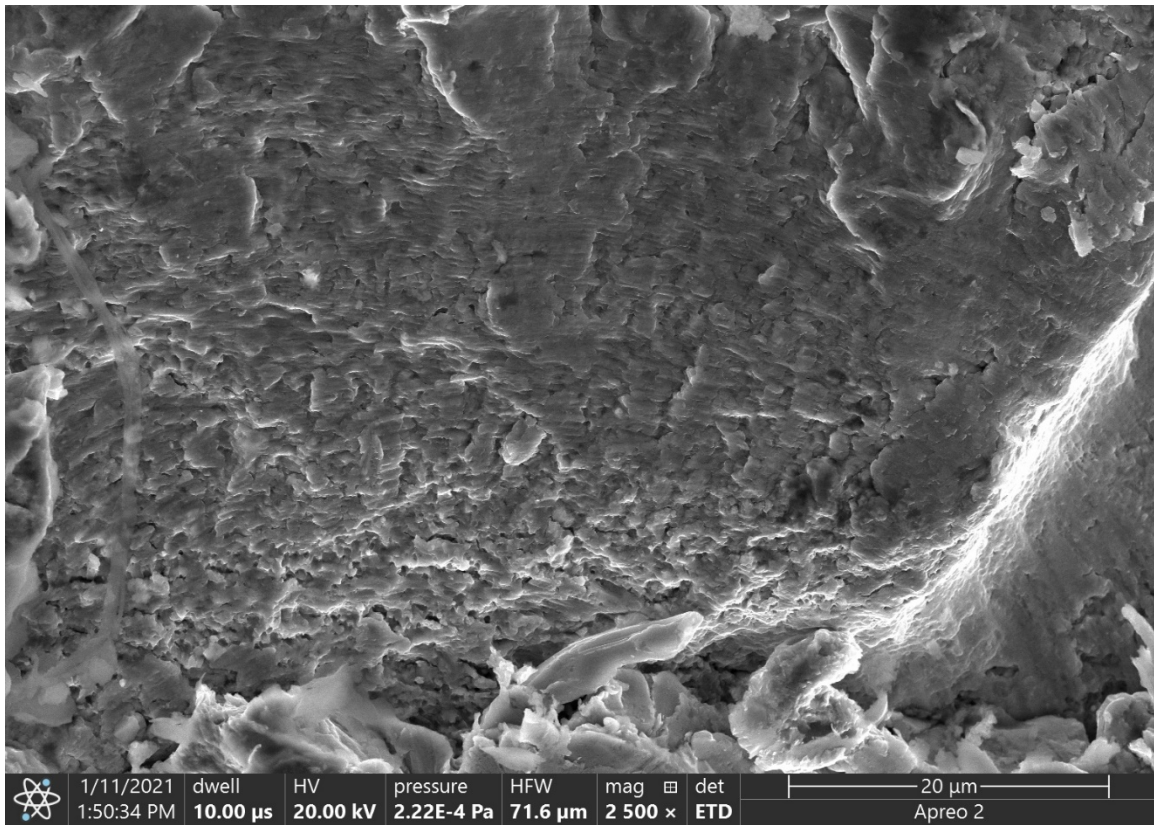


Figure 16 – SE micrograph of fatigue striations from the surface in Figure 15.

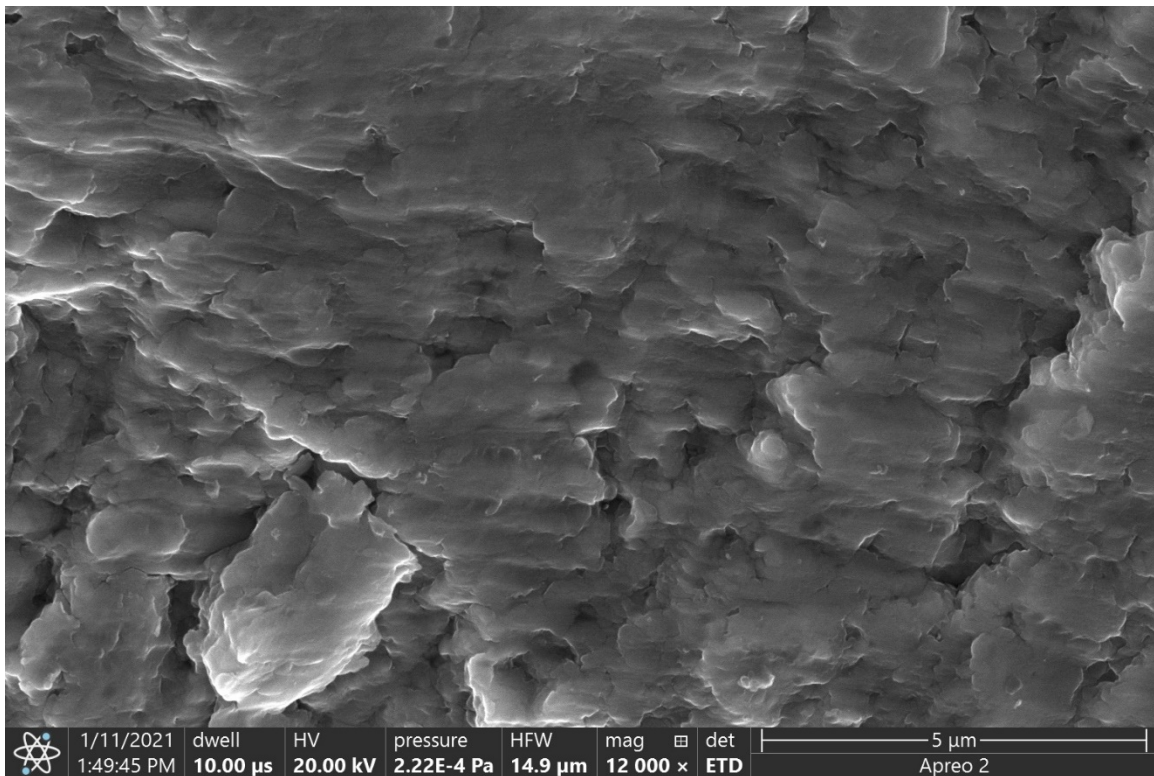


Figure 17 – SE micrograph showing a closer view of the striations in Figure 16.

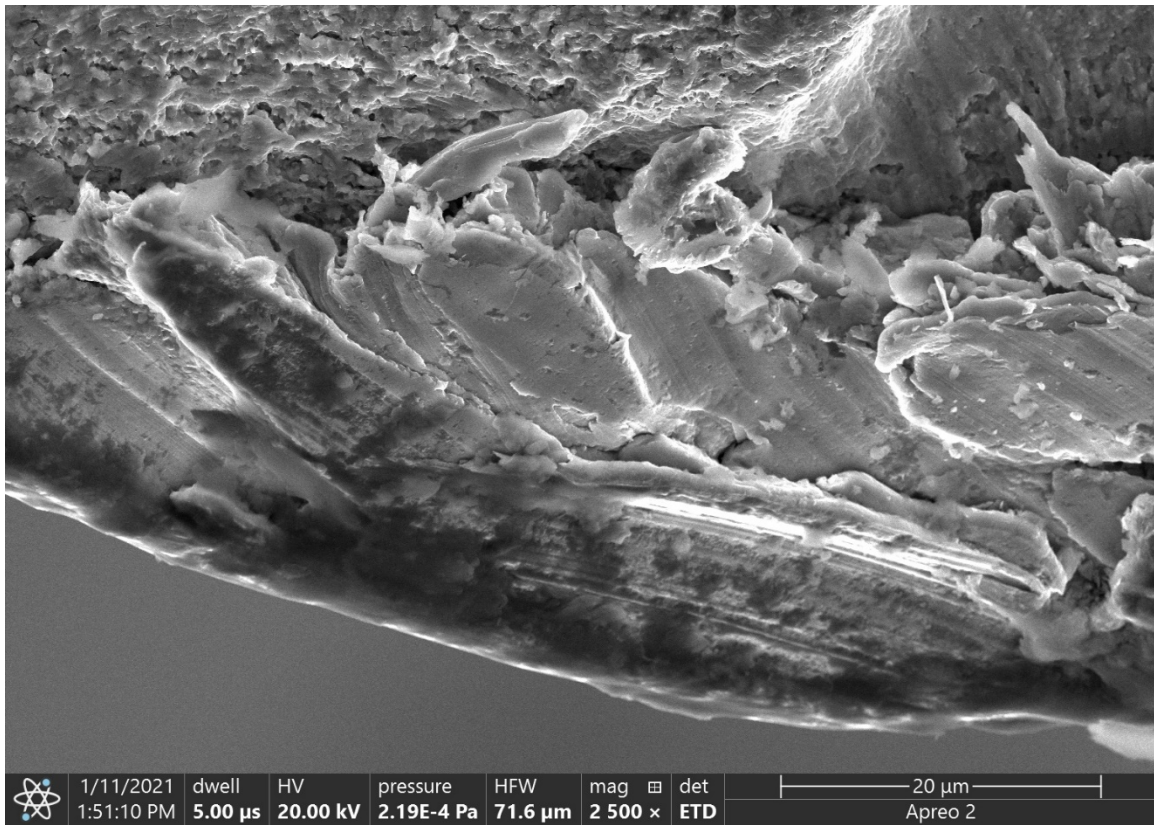


Figure 18 – SE micrograph of the damaged fatigue initiation site from Figure 15.

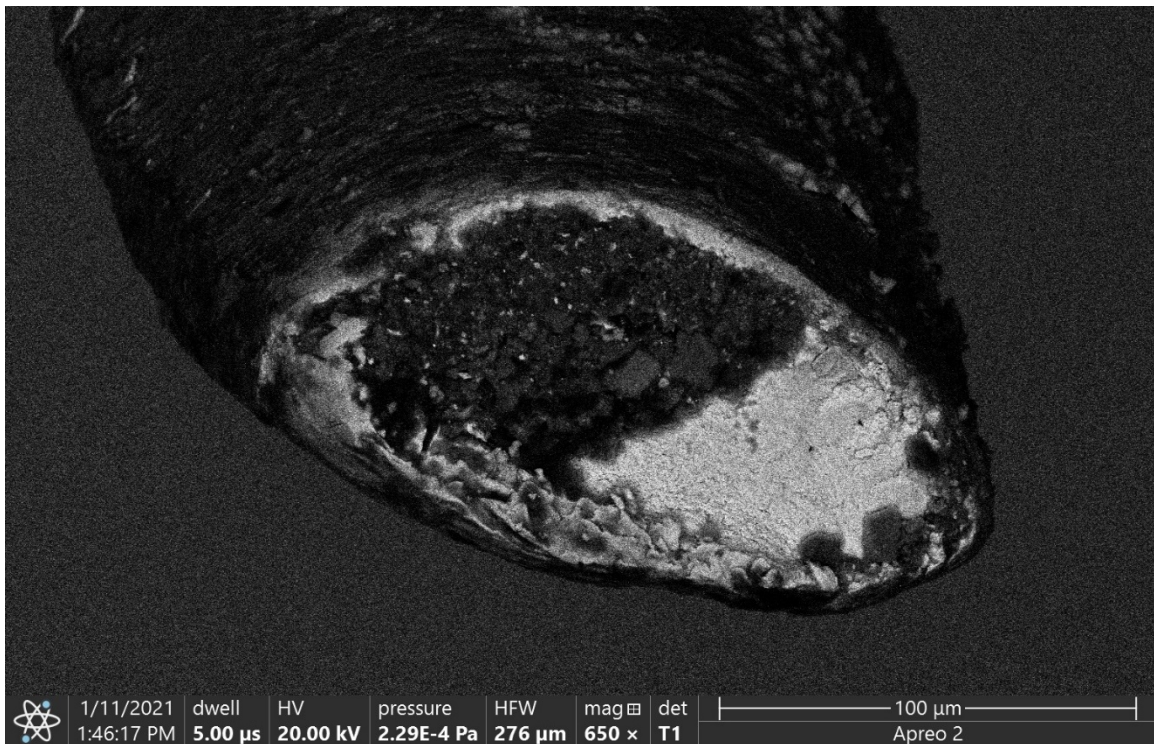


Figure 19 – Backscattered electron (BE) micrograph of a second wire with fatigue features, showing an oblong shape and surface contamination on the left.

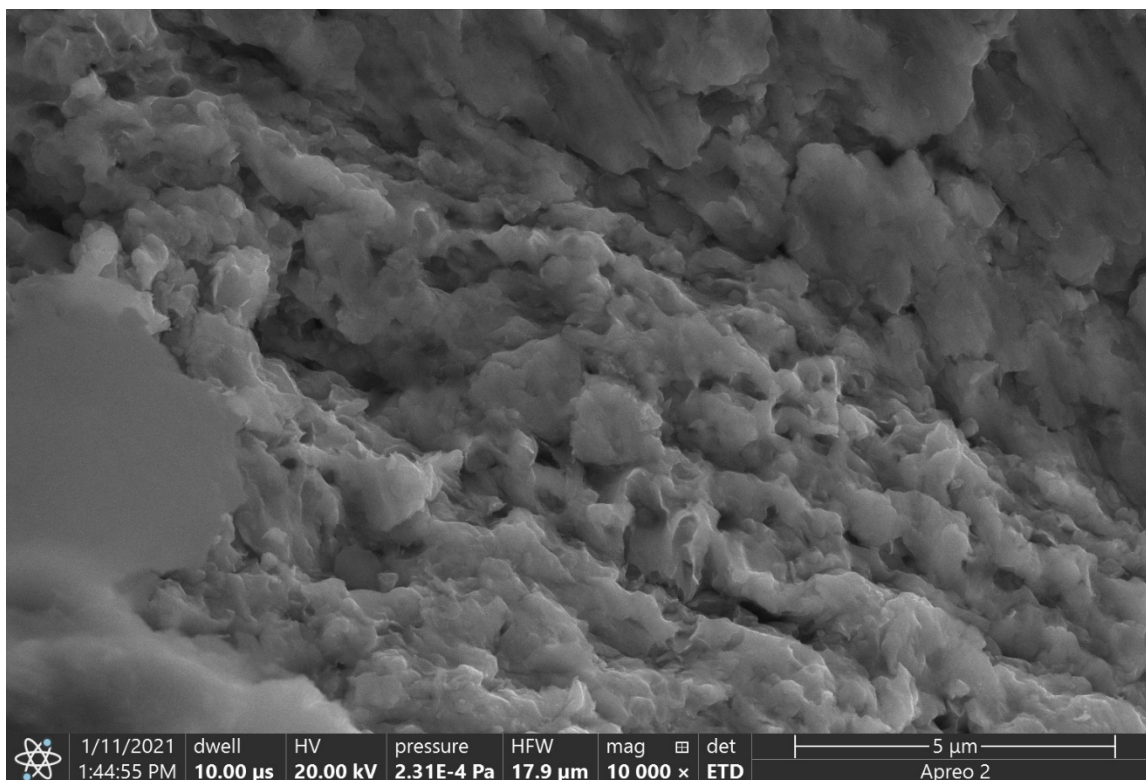


Figure 20 – SE micrograph of fatigue striations on the fractured wire in Figure 19.

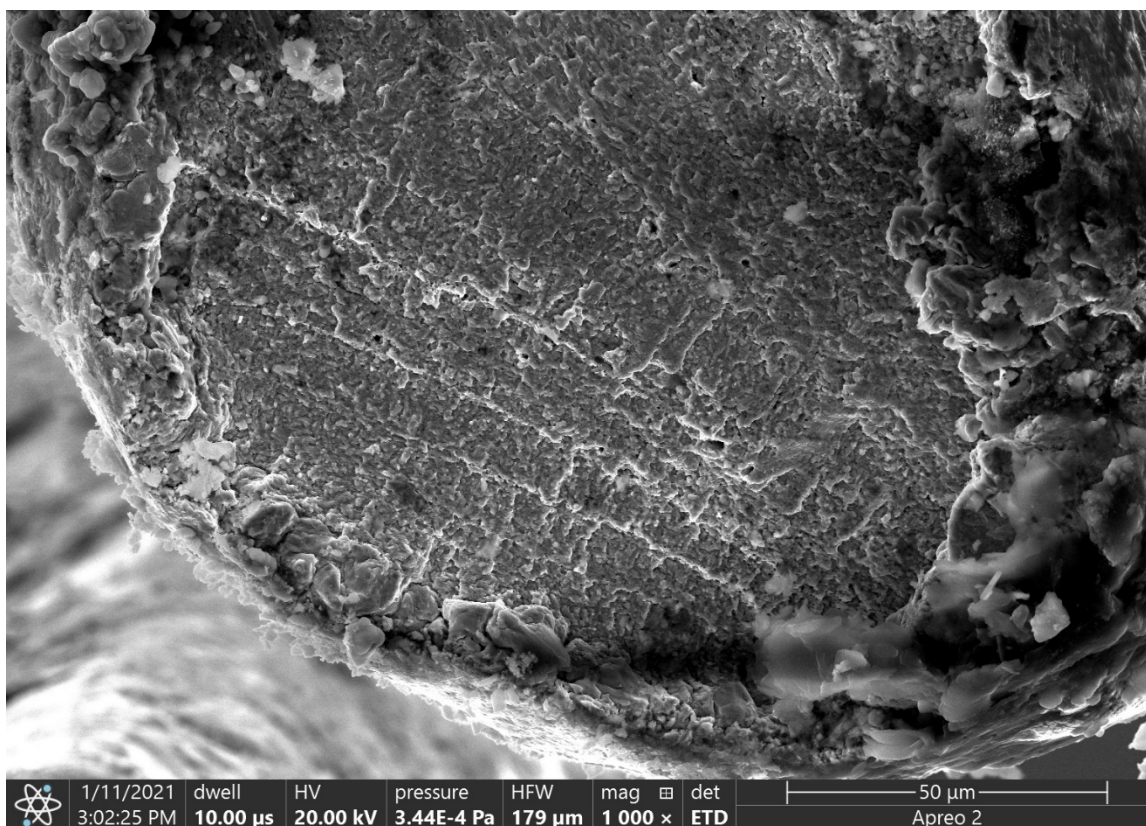


Figure 21 – SE micrograph of a third wire with fatigue features.

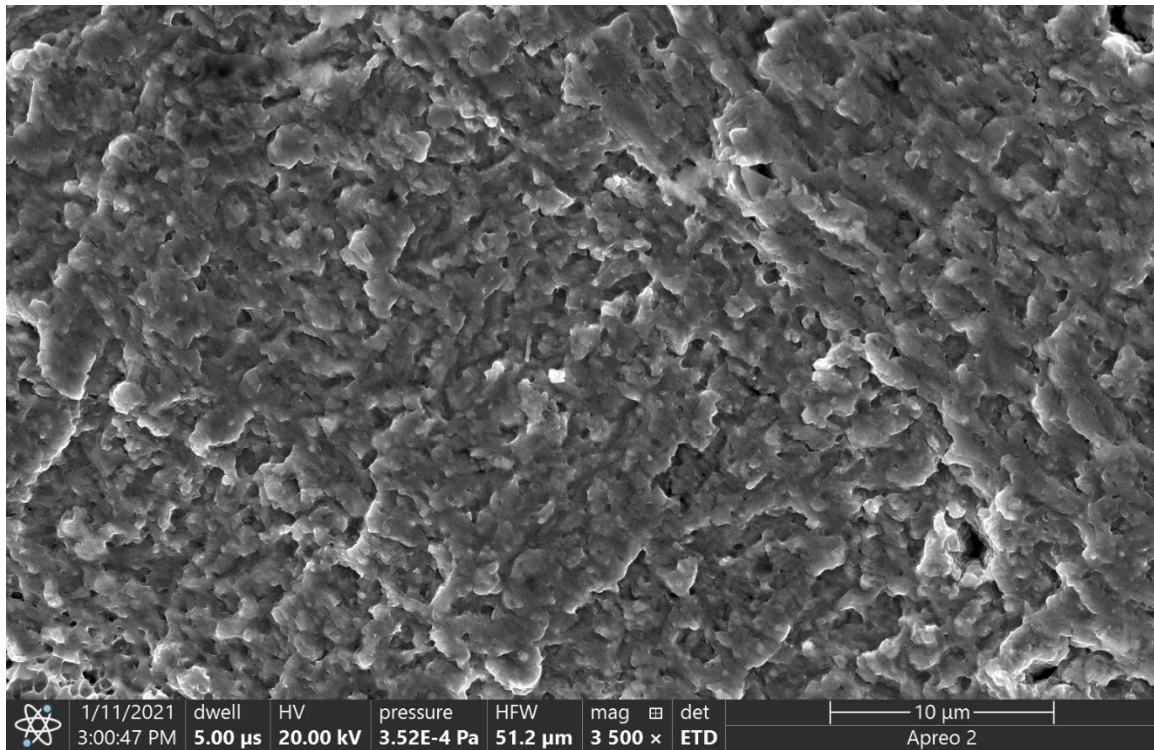


Figure 22 – SE micrograph of a closer view of fatigue striations on Figure 21.

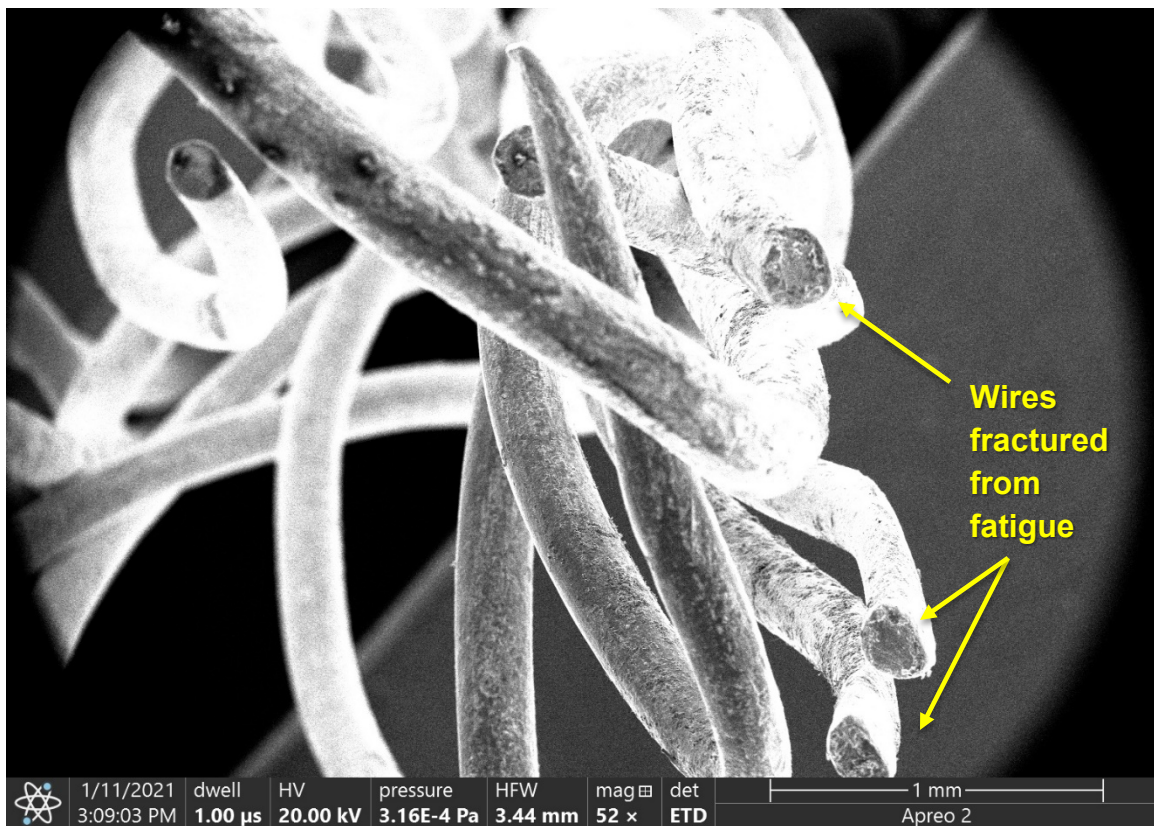


Figure 23 – SE micrograph of a second set of fractured wires, several with fatigue features.

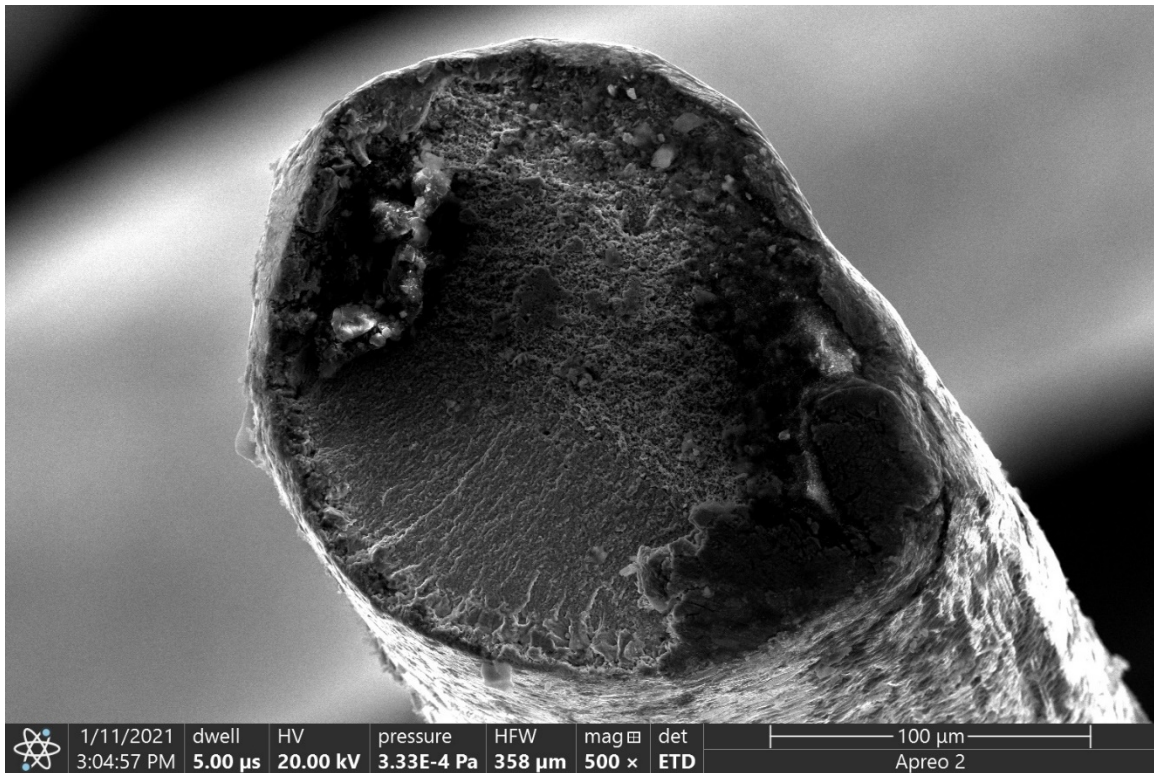


Figure 24 – SE micrograph of a fractured wire from, showing fatigue and overstress features.

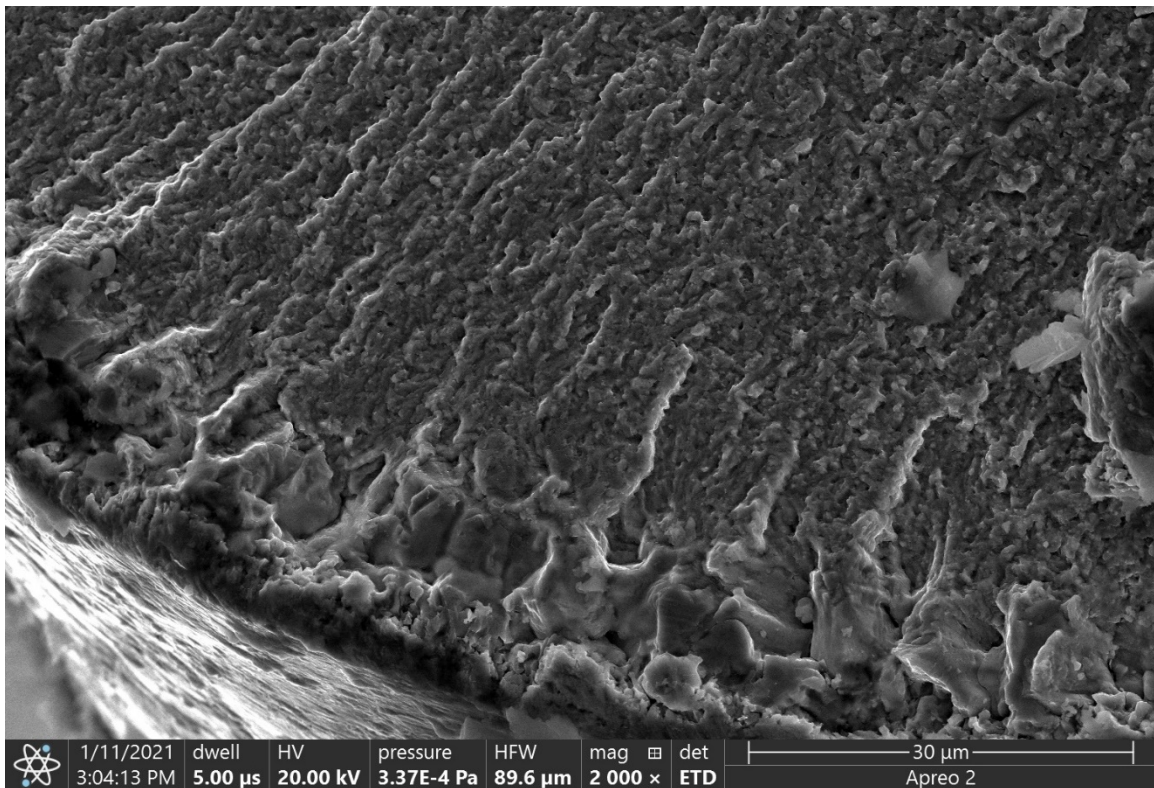


Figure 25 – SE micrograph of fatigue initiation sites of the wire in Figure 24.

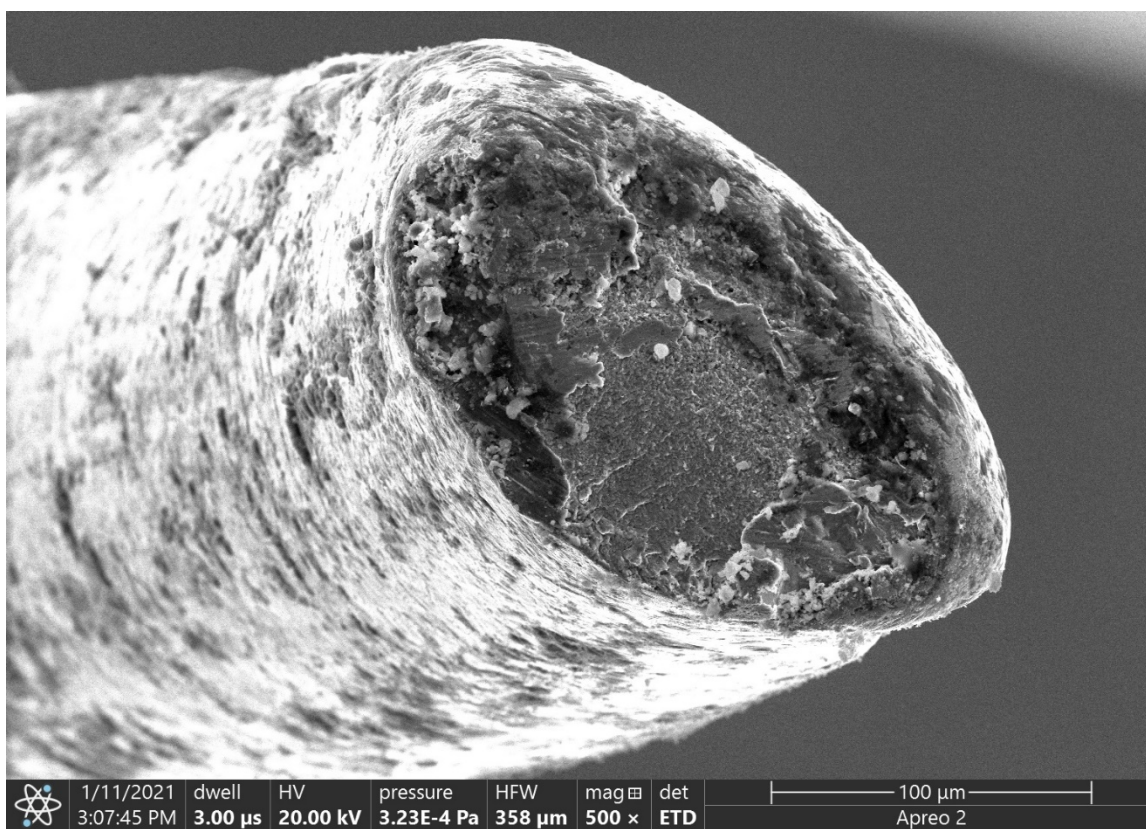


Figure 26 – SE micrograph of a pinched and fatigued wire from Figure 23.

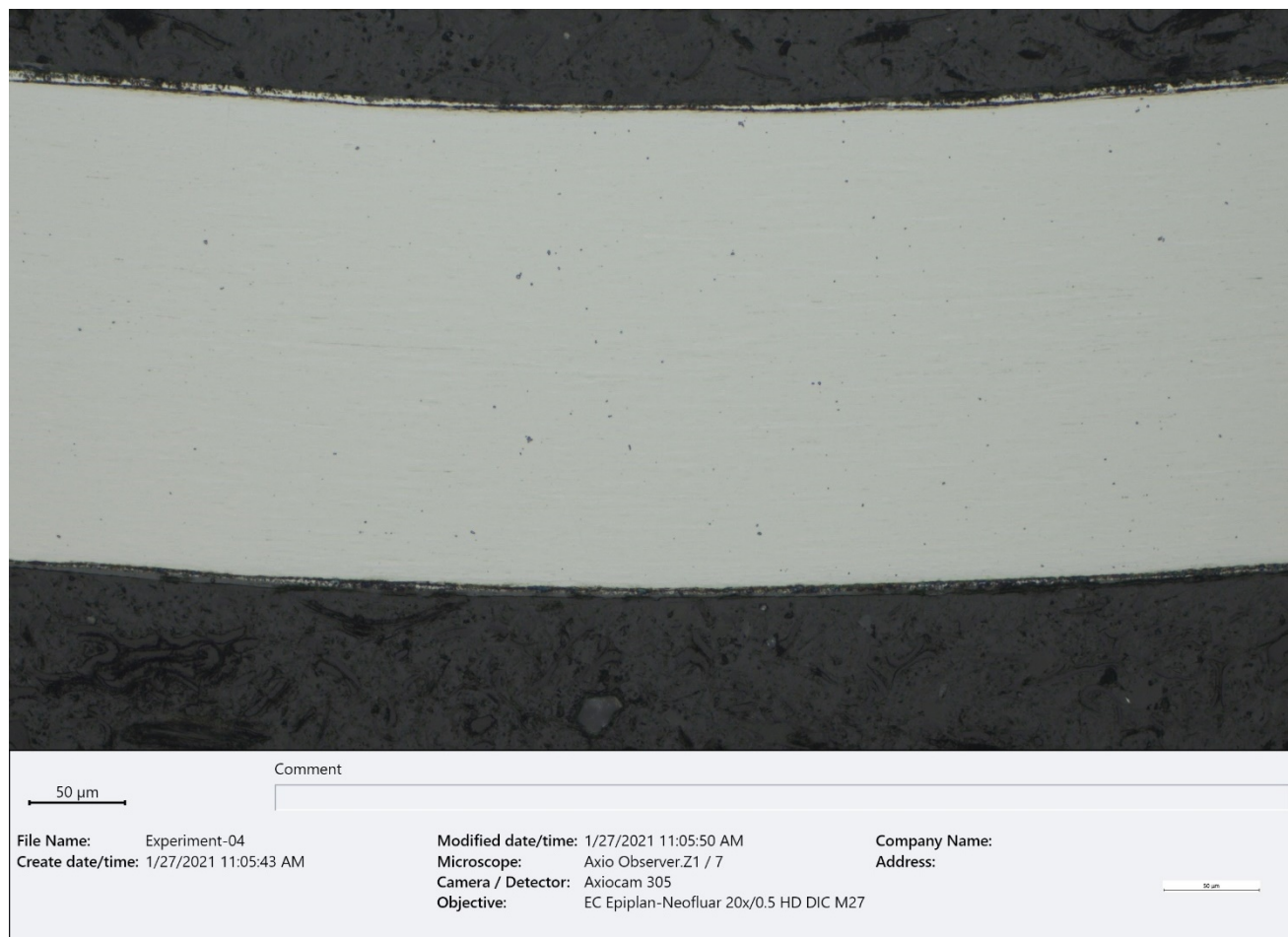


Figure 27 – Bright-field (BF) optical micrograph of a longitudinal (parallel) section of a wire, showing elongated grain structure along the drawing direction and a surface coating (~200X, as-polished).