

NATIONAL TRANSPORTATION SAFETY BOARD

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



April 28, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 22-026

1. ACCIDENT INFORMATION

Place : Mehama, Oregon
Date : July 17, 2020
Vehicle : Hiller UH-12D, N2297W
NTSB No. : WPR20LA224
Investigator : Samantha Link, AS-WPR

2. COMPONENTS EXAMINED

Remnants of tail rotor blade assembly
Remnants of a tail rotor gear box assembly

3. DETAILS OF THE EXAMINATION

On July 17, 2020, at about 0854 Pacific daylight time, a Hiller UH-12D helicopter was destroyed when it was involved in an accident near Mehama, OR. The pilot was fatally injured. The helicopter came to rest upside down, and a post impact fire consumed the cabin area and engine compartment. The operator reported that the turbine section of the engine had been removed and reinstalled three times in the past month due to continued problems with the engine. About a week before the accident, the helicopter was returned to service. The helicopter was recovered for further examination, and components from the tail rotor section were sent to the NTSB Materials Laboratory for additional examination.

Figure 1 shows one of the tail rotor blade assembly remnants, as received. The red painted blade exhibited a through hole near the blade tip, with crumpling and buckling in the location. This blade assembly remnant was still attached to the yoke and hub assembly, depicted on the left in Figure 1a and 1b.

Multiple connections facing the yoke and hub assembly had fractured, as depicted in Figure 2. These included the pitch change link rod end, a center coupling, and the bundle of tension-torsion (TT) straps. In addition, the joint between the cylindrical fitting and the inboard blade surface was loose, as depicted in Figure 3 and Figure 4. These mating surfaces had ground on each other such that no features could be discerned between the two components.

Figure 5 shows the opposite tail rotor blade assembly, which was no longer attached to the yoke and hub assembly. This blade also exhibited buckling, although to a lesser degree than the blade in Figure 1. There was also no indication of penetration or fracture of the blade. Further, the connection between the fitting and the blade was tight, with no indications of wear or grinding between the parts. The TT strap bundle in this blade was intact but cracked and bent, as discussed later. The pitch change link had also fractured on this assembly.

Figure 6 shows the fractured pitch change link remnants of each blade assembly, positioned to show the mating fracture surfaces. After disassembly, the fractured assembly with the outward-facing rod ends are shown in Figure 7. The fracture occurred in the housing cylinder at the end of the base of the right-facing rod end. There were no indications of buckling or out-of-plane deformation of this part.

One of the pitch change link fracture surfaces is shown in Figure 8. The fracture surface generally exhibited a 45° outward-facing slant. The surface itself was rough in texture and exhibited a dull luster. Flow lines and chevron marks were observed, consistent with fracture emanating from the safety wire holes. These features were consistent with overstress fracture of the link in tension.

As stated earlier, the tail rotor blade assembly that was still attached to the hub exhibited a fractured series of TT straps protruding out of the opposite fitting. This bundle consisted of 10 of the 11 straps. The mating tail rotor blade assembly contained one TT strap. These fractured remnants of each blade assembly are depicted in Figure 9 to demonstrate their positions at fracture. One of the straps had fractured at the inboard bolt, whereas the other 10 had fractured at the outboard bolt.

This fractured TT strap bundle, as well as the strap bundle from the inside the loose blade/fitting assembly in Figure 3, are depicted side-by-side in Figure 10. As mentioned earlier, the fractured bundle exhibited fracture surfaces perpendicular to the bar direction at the fastener bore, whereas the intact bundle had exhibited only one fractured strap.

This one fractured strap on the upper bundle in Figure 10 had broken at the neck (Figure 11) along the location of a bend in all of the straps (see the side view in Figure 12). The series of straps exhibited a concave upward facing curve in Figure 12, consistent with upward bending. The fractured strap was located on the side with the maximum tension. This strap also exhibited necking and deformation adjacent to the fracture surface (see Figure 11). The upper edge in Figure 11 exhibited pronounced necking on the bottom surface, with S-shaped buckling on the upper edge. These features were consistent with an additional bending axis towards the upward direction in Figure 11.

Figure 13 shows a closer view of one of the mating strap fracture surfaces. This surface exhibited a slanted 45° orientation. While the bottom long edge exhibited a more reflective luster, this was consistent with post-fracture damage from smearing and wear—the mating fracture surfaces were still in contact at disassembly. The undamaged areas of

the strap fracture surface exhibited a dull, rough texture. These features were consistent with fracture from tensile overstress of this strap.

Figure 14 shows the end where most of the straps had fractured at the plain bearing, with the one strap that was still intact upon receipt. The straps that had fractured did so approximately 0.41 inches from the rounded end. The intact strap exhibited a diameter of 0.561 inches along the longitudinal direction, and 0.505 inches along the transverse (perpendicular) direction.

The fractured set of TT straps are shown from the side in Figure 15. Approximately 1.25 inches from the fracture at the fastener bore, there were sideways pinch marks. This left of this location, the straps were adjacent to and parallel with each other. To the right in the figure, the outer straps flared outward on either side of the bundle.

Figure 16 shows the collective fracture surfaces of the bundle from Figure 15. The straps were clamped together to facilitate the positioning in Figure 16. Collectively, the fracture surfaces on the right exhibited features similar to that of the singular fractured strap in Figure 13—the fracture surfaces were dull in luster and rough in surface texture, with necking and twisting deformation near the fracture surface. The features of the right side fracture surfaces in Figure 16 were consistent with overstress fracture.

The left side fracture surfaces of the TT straps, highlighted in Figure 17, exhibited a different surface morphology. Towards the fastener bore, the fracture surfaces exhibited a flat surface, oriented perpendicular to the rolling direction of the strap. Opposite or outboard of the fastener bore, the fractures were rougher, with inward pinching or necking. The outboard areas of the fracture were generally duller in luster and rougher in texture than the inboard regions.

Highlighted in Figure 18, the flatter, inboard areas of the TT strap fracture surfaces exhibited repeating features consistent with crack arrest marks. Towards the edge with the bore, the surfaces exhibited horizontally-oriented linear features consistent with ratchet marks. These features were consistent with progressive cracking, later determined to be fatigue, propagating from multiple initiation sites along the bore.

One of the outermost straps in this bundle was sectioned and cleaned with acetone for examination in a field emission scanning electron microscope (SEM). Figure 19 shows a typical area of the fatigue fracture. Closer examination of this area revealed fatigue striations, consistent with fatigue crack propagation, as typified in Figure 20. The nature of the striations was consistent with crack propagation from the inboard fastener bore outward.

All of the fractured straps exhibited fatigue cracking that had progressed part way through the part cross section. At the transition to the end of the crack, as depicted in Figure 21, the fracture surface transitioned from a relatively flat surface to an angled and curved orientation, with localized necking along the edges.

At higher magnifications, the flat area still exhibited fatigue striations (see Figure 22), whereas the area outboard exhibited dimpled rupture (see Figure 23). These features were consistent with fatigue propagation through each strap cross section, until the remaining material could no longer withstand the stresses, fracturing in subsequent overstress.

Figure 24 shows the crack initiation site(s) of this fracture strap in secondary and backscattered electron modes. The initiation of the fatigue crack occurred on the edge with the inside fastener bore. As shown in both figures, there was a pronounced ratchet mark along the center, consistent with separate cracks joining during propagation after initiation at multiple initiation sites. Figure 25 shows a closer view of the more pronounced initiation site, along the edge, and Figure 26 shows an angled view of the initiation site edge with the bore surface. This area exhibited some dissimilar material, with the darker gray being consistent with post-fracture oxides of the metal alloy, and the dark material being consistent with post-fracture contamination.

The view in Figure 26 shows propagation flow lines emanating primarily from two points along the edge, which exhibited some smearing and rounding. There were no indications of pitting or inclusions along the fatigue crack initiation sites. However, below and adjacent to the crack initiation sites were areas of wear, manifest as horizontal lines in Figure 26, oriented parallel to the fracture surface. As also seen visually in Figure 18, these marks were consistent with wear of the straps along the cylindrical surface of the adjacent fastener. There were also areas with flaky divots, as typified in Figure 27. These features were consistent with features common in spalling and galling of faying surfaces.

The plain bearing at the location of the fractured TT strap location is illustrated in Figure 28, which also shows one of the washers that was outside the bundle stack. The bearing exhibited outward flaring on one side. Near the flaring was a circumferential worn area, along with a worn area near the opposite edge. These worn areas were consistent with the thickness of the washers. The central cylindrical surface also exhibited areas of wear, as illustrated in Figure 29. This showed circumferential as well as pronounced longitudinal wear. In areas consistent with spalled material, fine dimpled rupture was observed, as illustrated in Figure 30.

These areas were inspected using energy dispersive x-ray spectroscopy (EDS). Figure 31 shows a typical EDS spectrum of a clean and polished area of the strap—the composition of the TT strap was consistent with an austenitic stainless steel. The area of the spalled divot and dissimilar material in Figure 26 was also examined using EDS. This was found to be a dissimilar composition, consistent with an aluminum alloy (see Figure 32). The aluminum alloy was inconsistent with the composition of the plain bearing, which was consistent with alloy steel. EDS examination of the bearing and washer found them both to be consistent with cadmium-coated steels and were absent any indications of aluminum alloys.

One set of TT straps fractured from fatigue cracking that occurred in 10 of the 11 straps. Once the cracks had propagated more than halfway through the cross section, the

straps fractured from overstress. The cracks initiated at the bore with the fastener and bushing, were spalling, galling, and wear marks were observed. The remaining adjacent structures in the tail fracture assembly fractured from overstress after this sequence.

According to the component replacement schedule, the TT strap bundles are to be replaced every 12500 flight hours. According to the maintenance logs of this aircraft, the components were installed at aircraft time 17362.5, making the time since new for the parts 11181.7 flight hours.

In addition to the tail rotor blade and hub assemblies, the remnants of the tail rotor gear box were also received by the NTSB Materials Lab. The gear box assembly remnant is shown in Figure 33 and Figure 34, as received. The housing with the gearing components was still intact. However, the skin of the adjacent housing had fractured in multiple locations, with tearing, deformation and buckling around the fractures. These features were consistent with later overstress fracture.

The connection cables and wires to the left in Figure 33 and Figure 34 were frayed and fractured. In addition, the shaft towards the right of the gear box had bent, but not fractured, in the figures. Several of the pinion teeth had also been deformed and worn.

Erik M Mueller
Materials Research Engineer

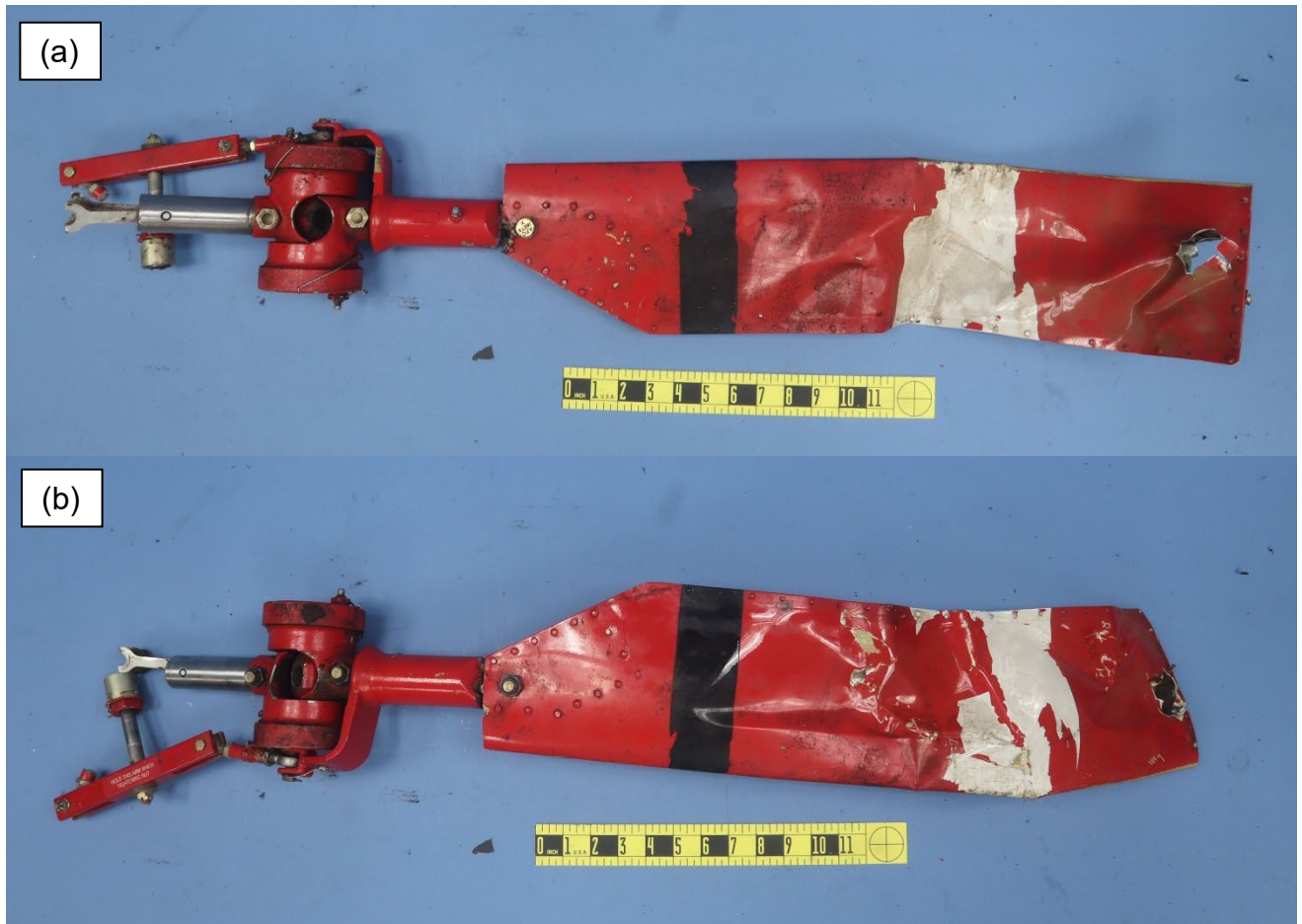


Figure 1 – Opposite views of the tail rotor blade assembly that was still attached to the hub and yoke assembly (left).

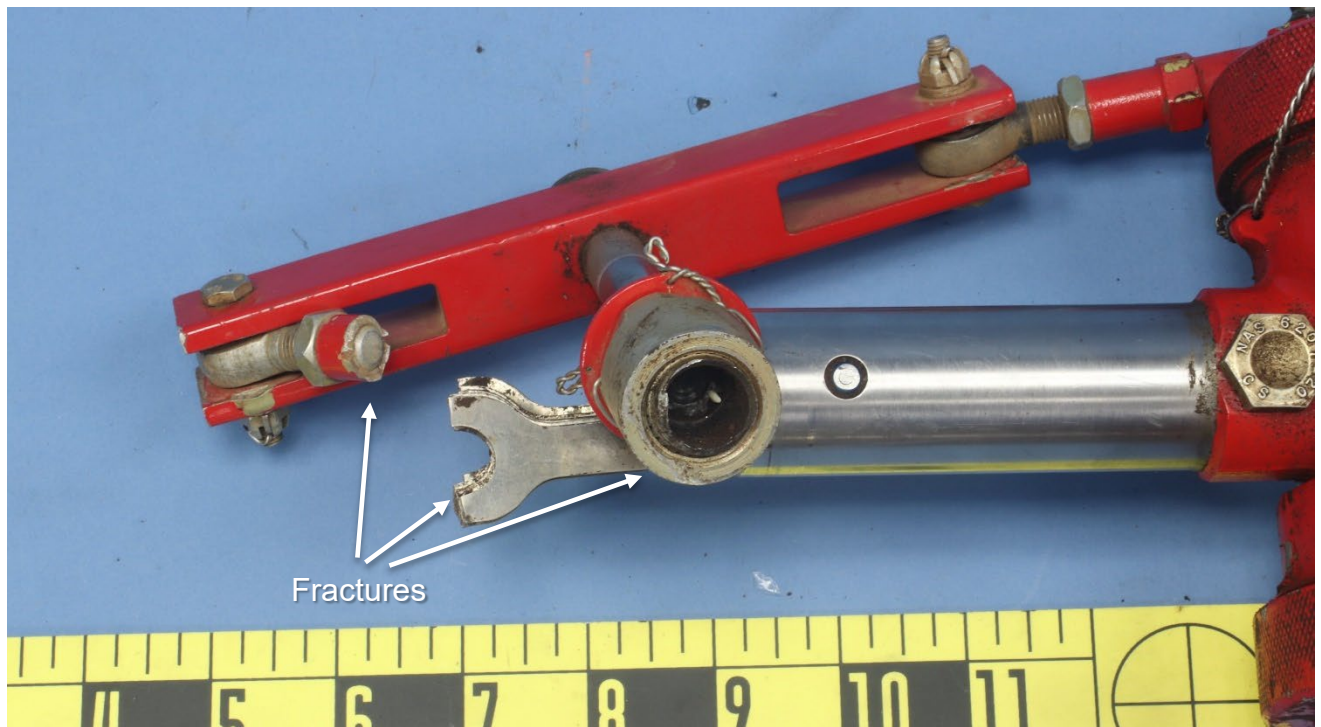


Figure 2 – Views of the fractured coupling, tension-tosion straps, and rod end from the assmebly in Figure 1, as received.

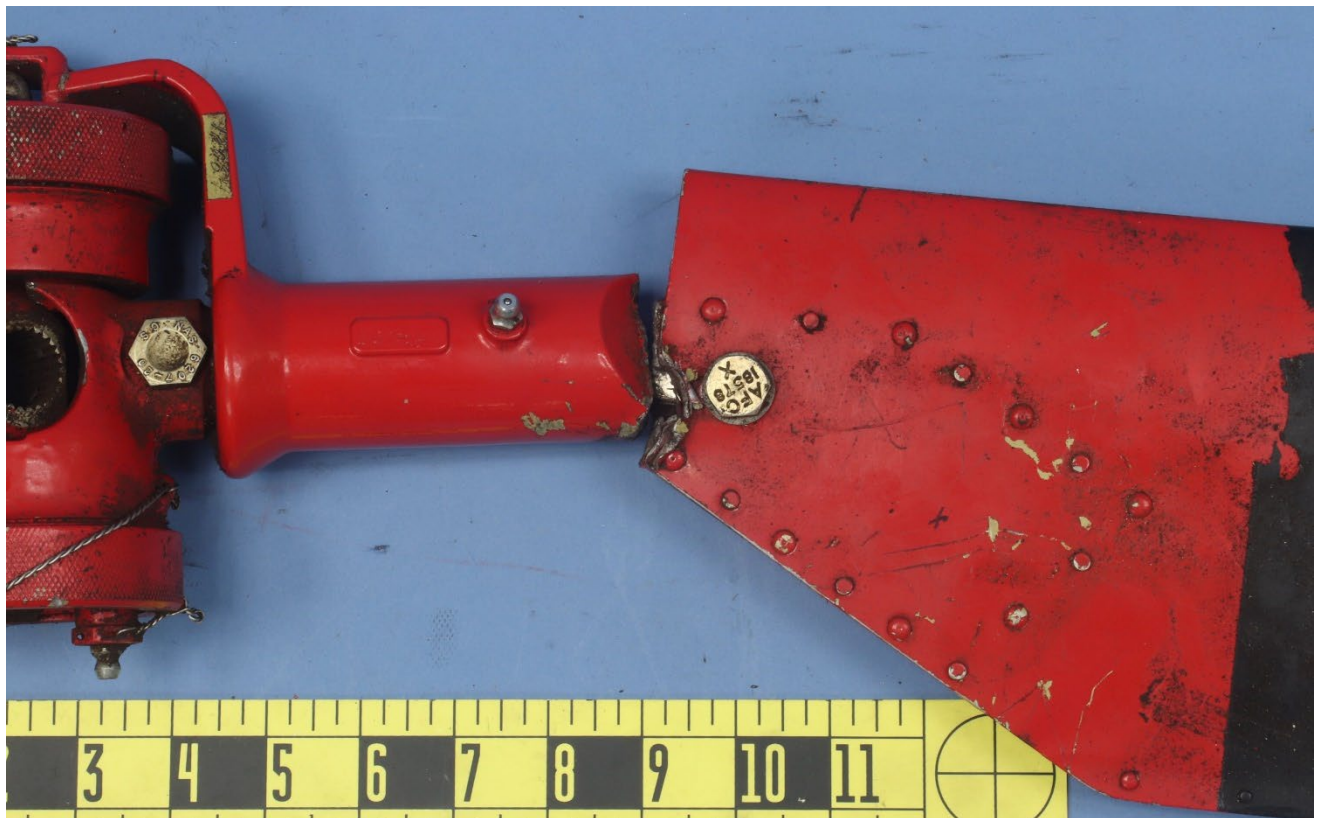


Figure 3 – View of the joint between the tail rotor fitting assembly and the blade, showing wear and grinding between the parts.

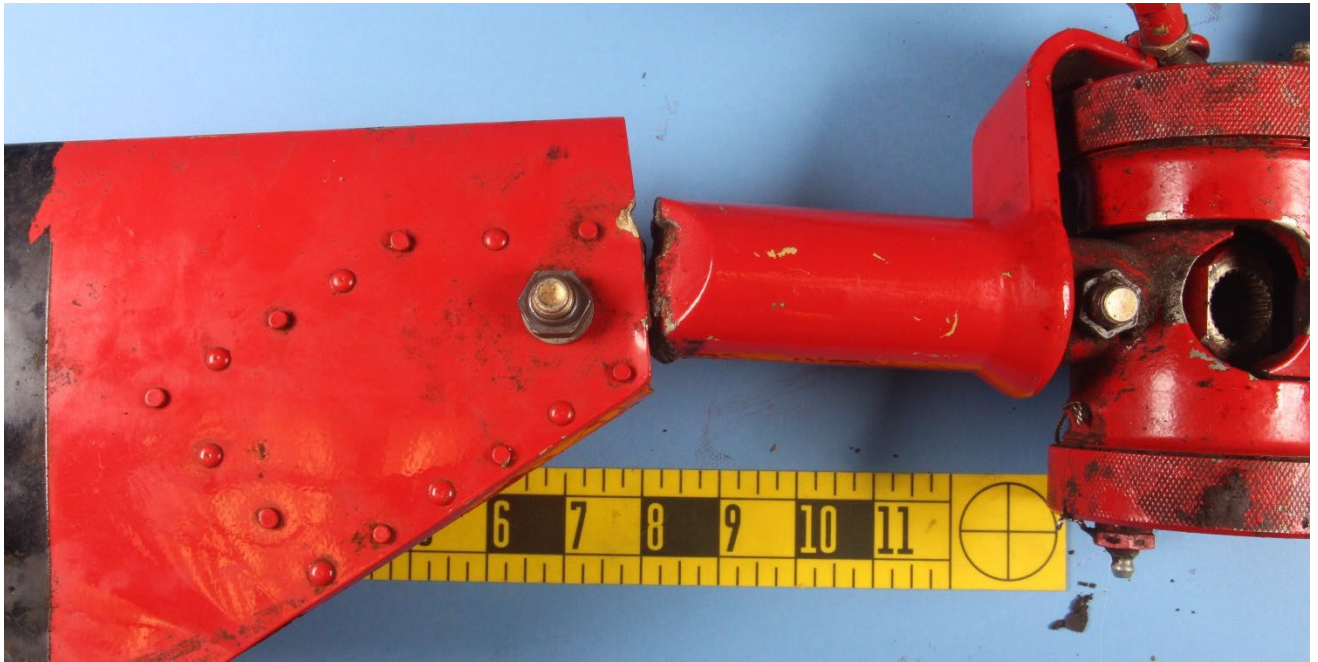


Figure 4 – Opposite view of the fitting and blade joint in Figure 3.

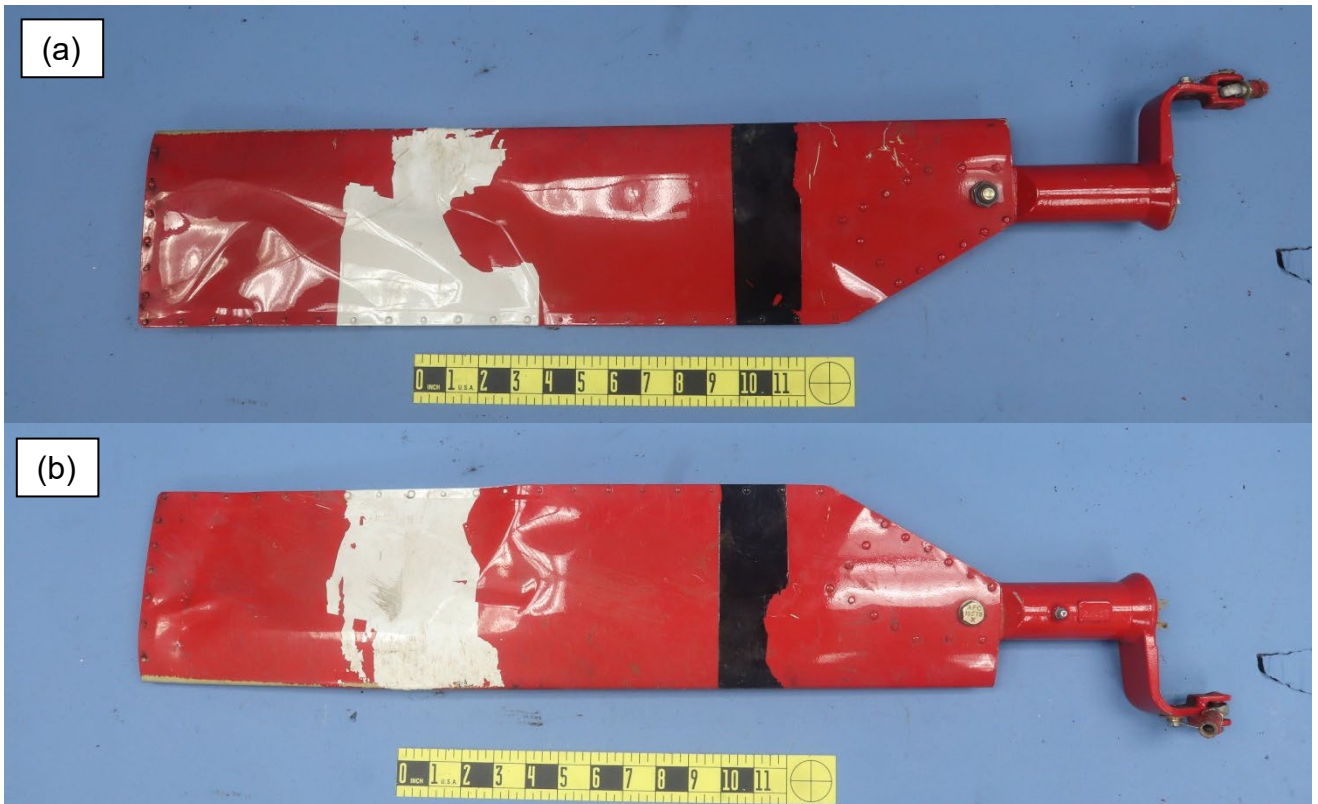


Figure 5 – Opposing views of the tail rotor blade assembly not attached to the hub and yoke assembly, as received.



Figure 6 – Views of the fractured remnants of a pitch change link, as received.

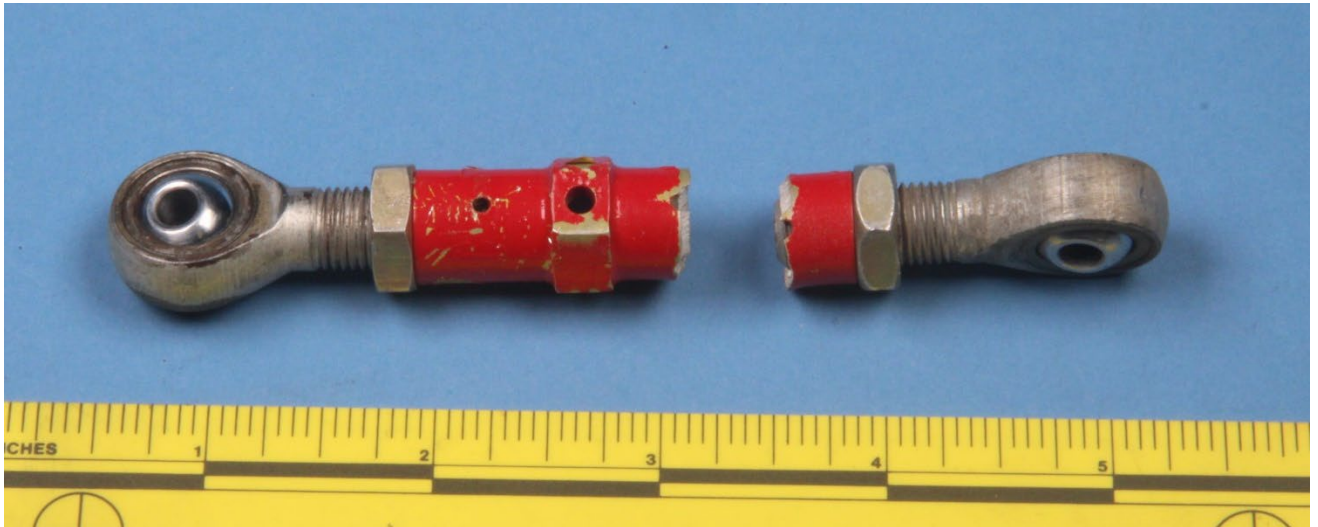


Figure 7 – Views of the fractured pitch change link rod ends from Figure 6, after disassembly and removal.



Figure 8 – View of the rod end fracture surface.

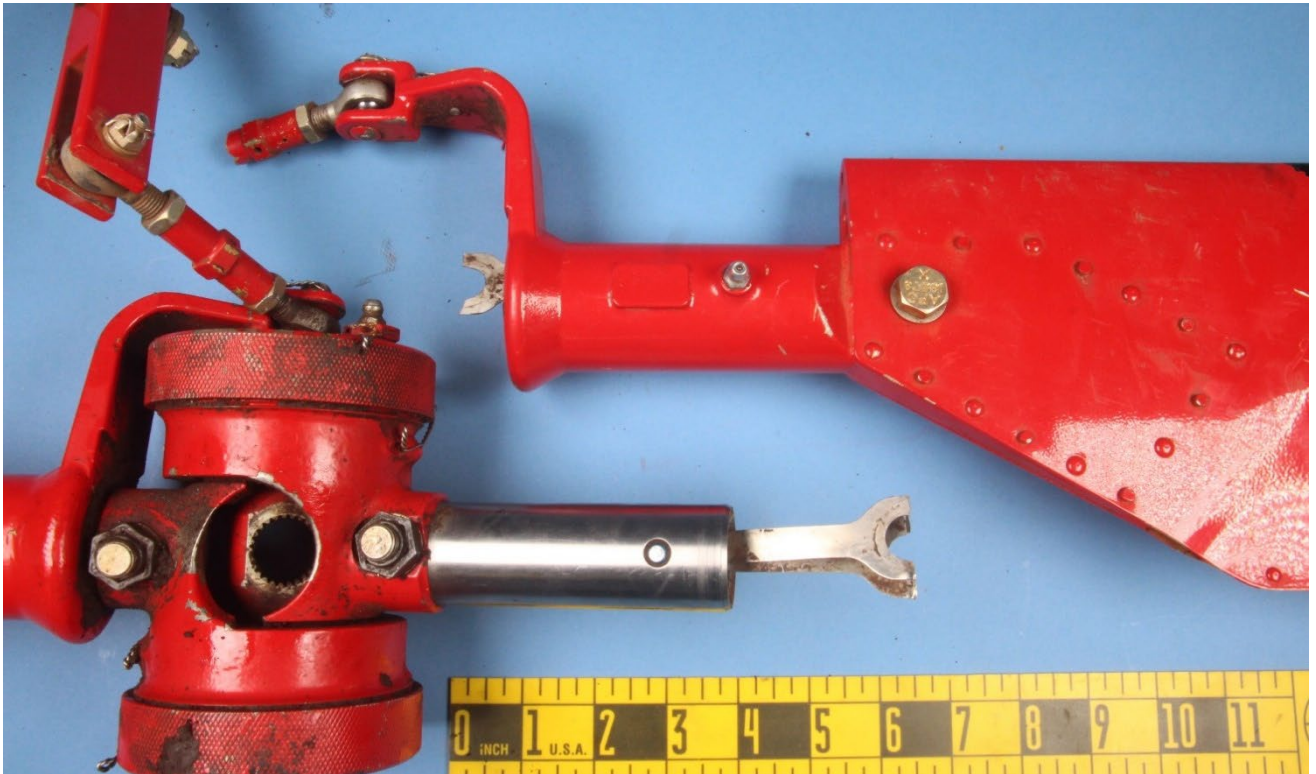


Figure 9 – Views of the fractured tension-torsion straps, positioned from the hub and blade assembly sides.

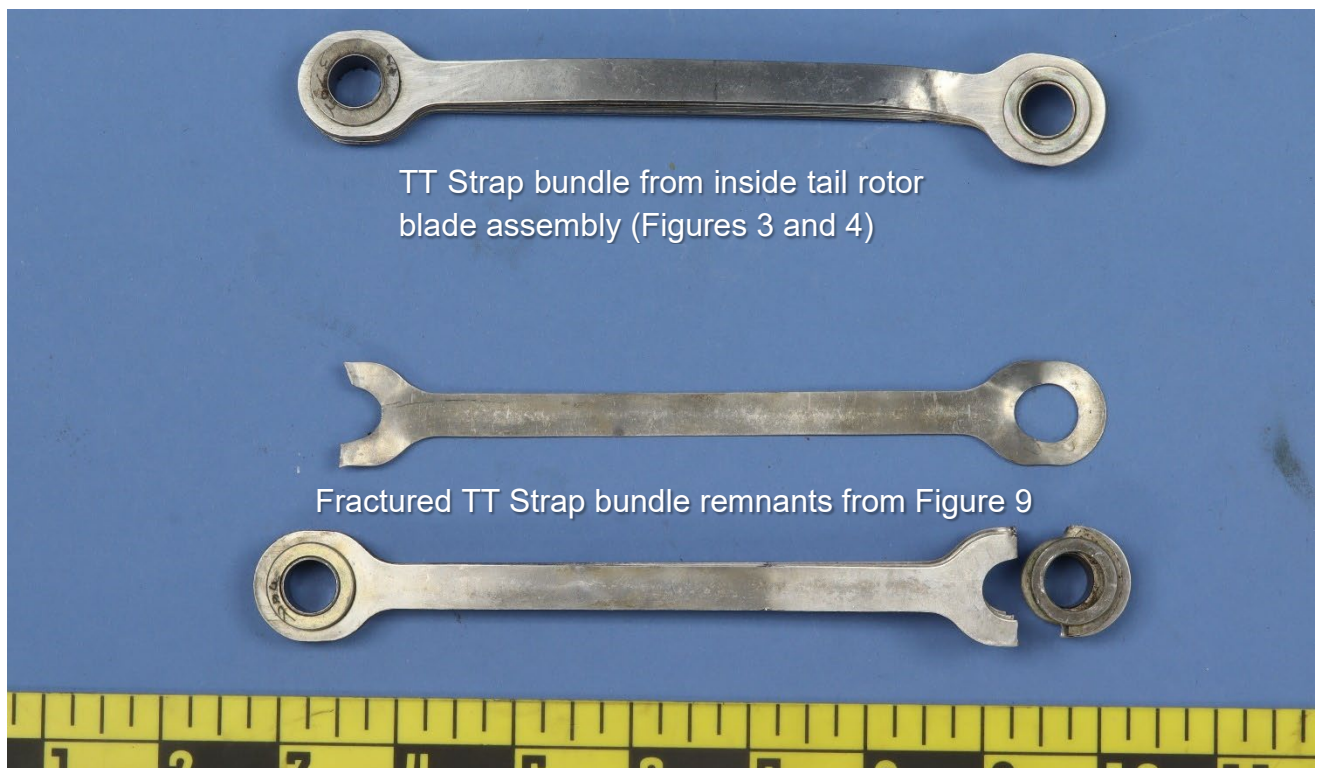


Figure 10 – Views of the sets of tension-torsion straps, after disassembly and removal.



Figure 11 – View of the deformed and fractured TT strap bundle from the second blade assembly, showing necking and buckling near the fracture of the outer strap.



Figure 12 – Side view of the TT strap bundle in Figure 11, showing the fractured strap facing downward at the bend in the set.



Figure 13 – View of the fracture surface of the fractured strap in Figure 11, showing a slanted orientation.



Figure 14 – The fractured ends of 10 of the 11 TT straps in the bundle, along with the one intact strap, exhibiting elongation.

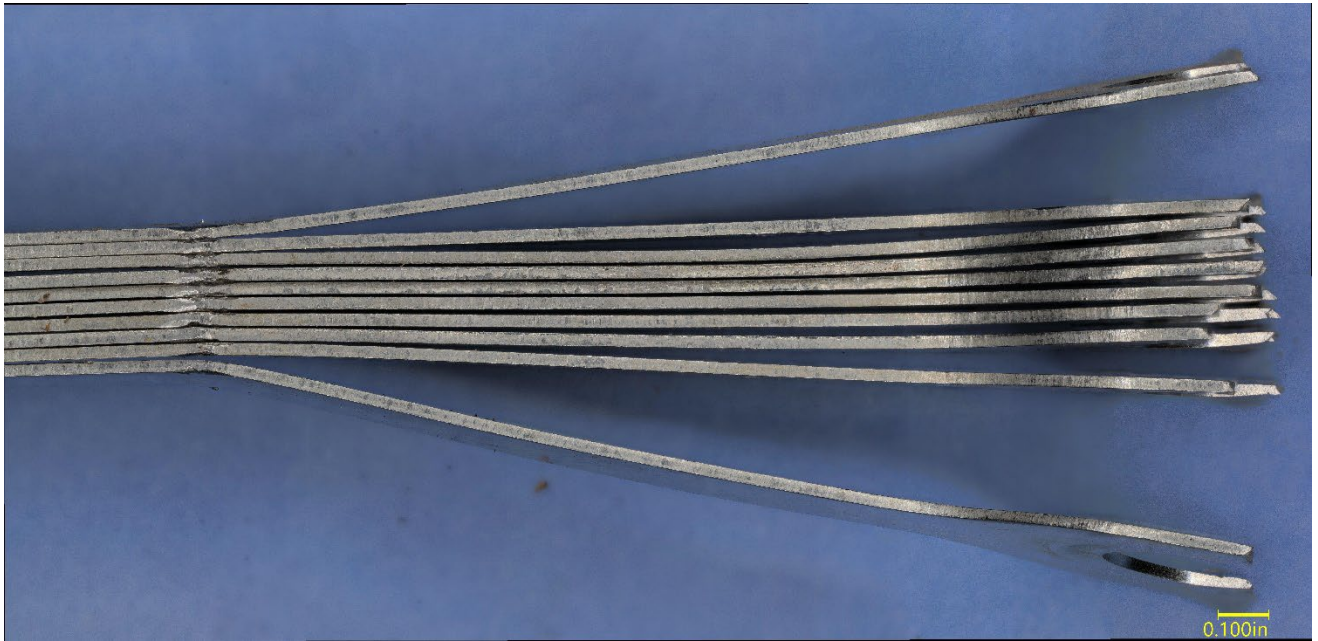


Figure 15 – Side view montage of the TT strap bundle from the rotor blade assembly in Figure 1, showing spreading at a bend, with 10 of the straps having fractured.



Figure 16 – View of the fracture surfaces of the bundle of TT straps in Figure 12.

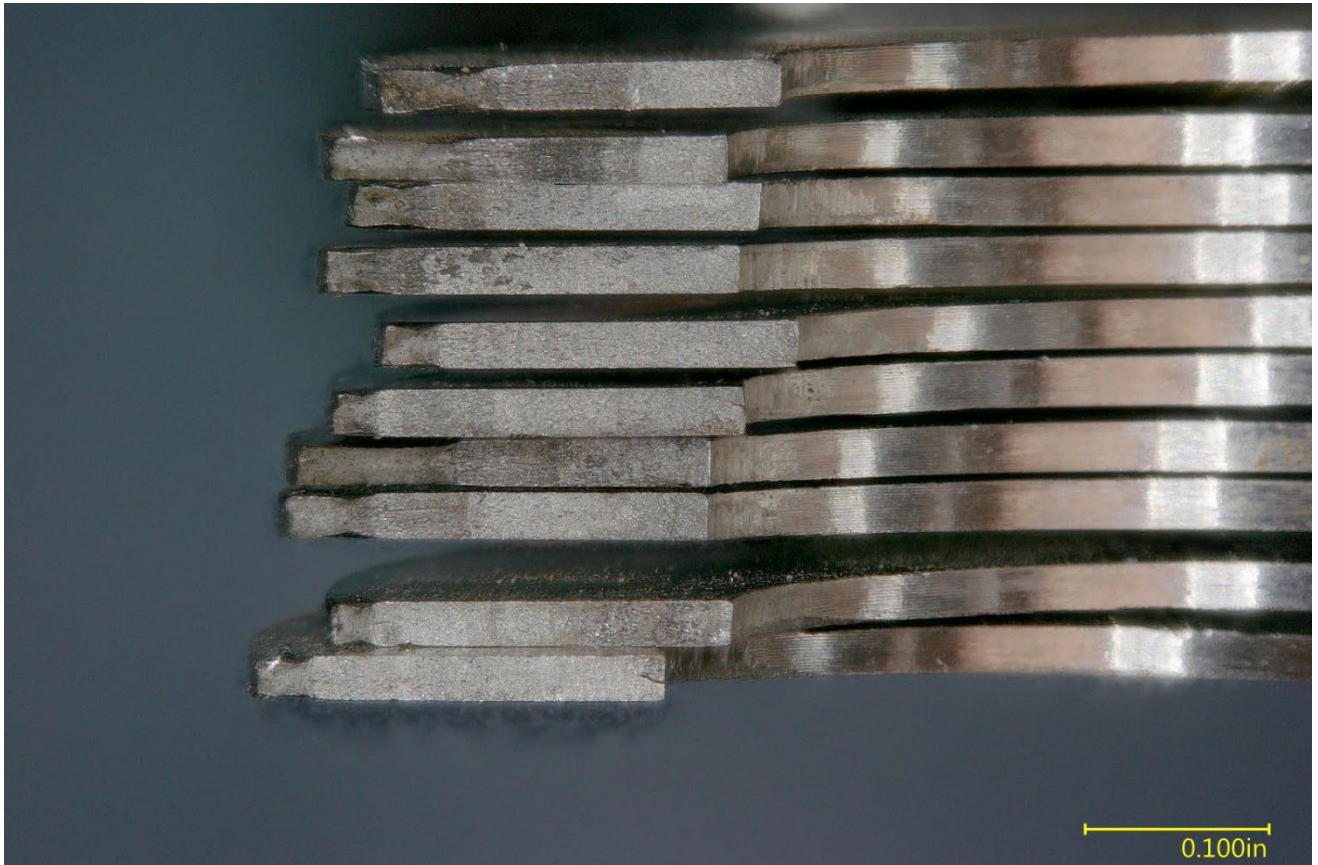


Figure 17 – Closer view of the left fractures on the TT straps in Figure 16, showing flat features inward and necked features outward.



Figure 18 – Closer view of several of the TT strap fracture, showing faint crack arrest marks emanating from the bushing bore.

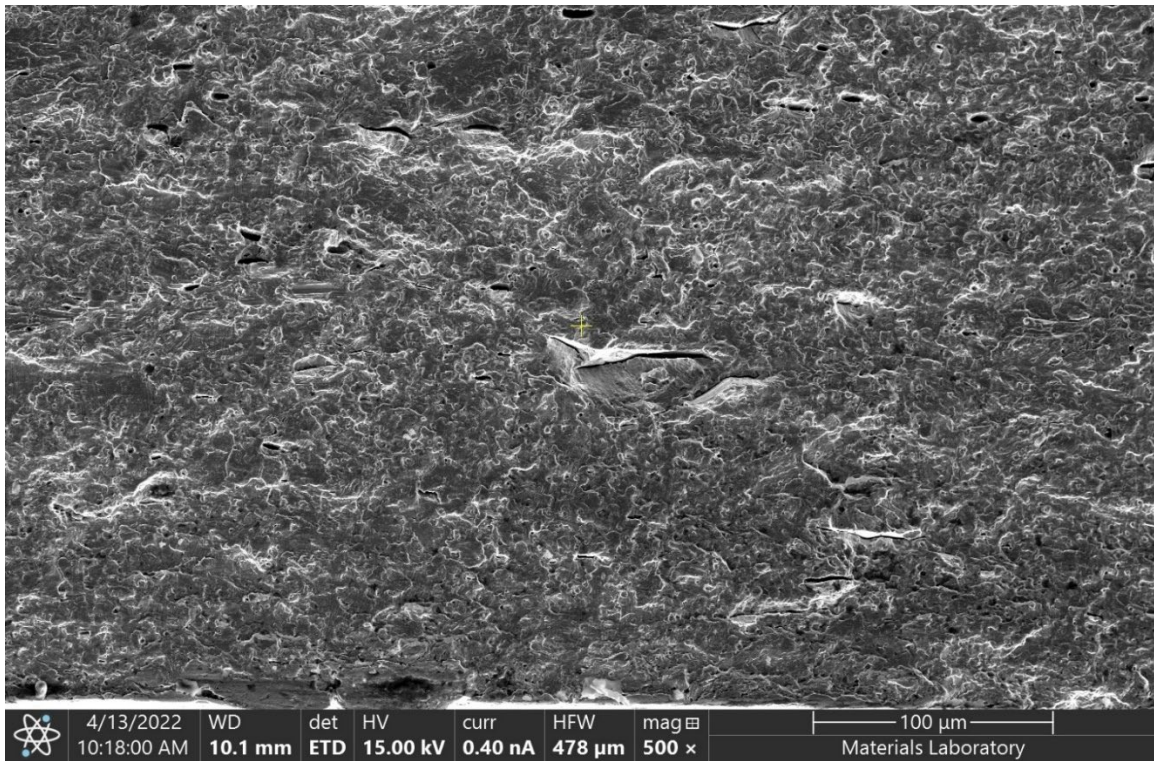


Figure 19 – Secondary electron (SE) micrograph of one of a typical area of the flat fracture on a TT strap in Figure 18.

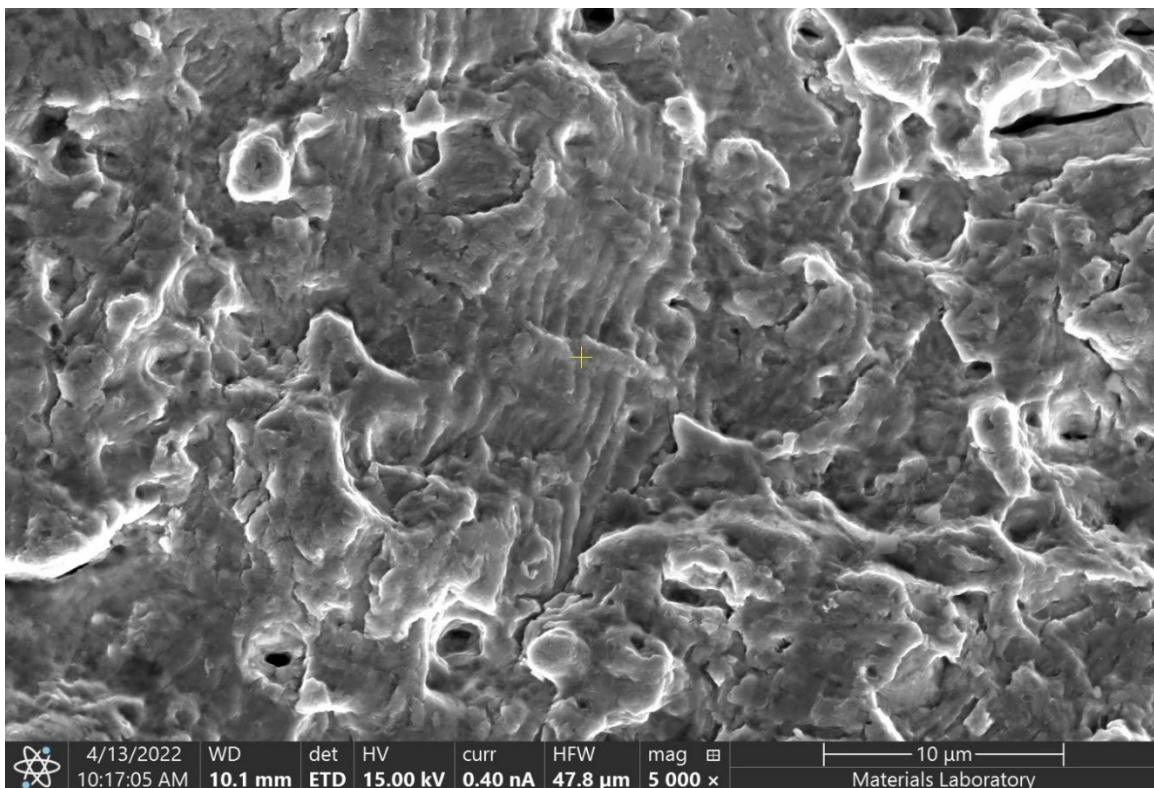


Figure 20 – SE micrograph of a closer view in Figure 19, showing fatigue striations.

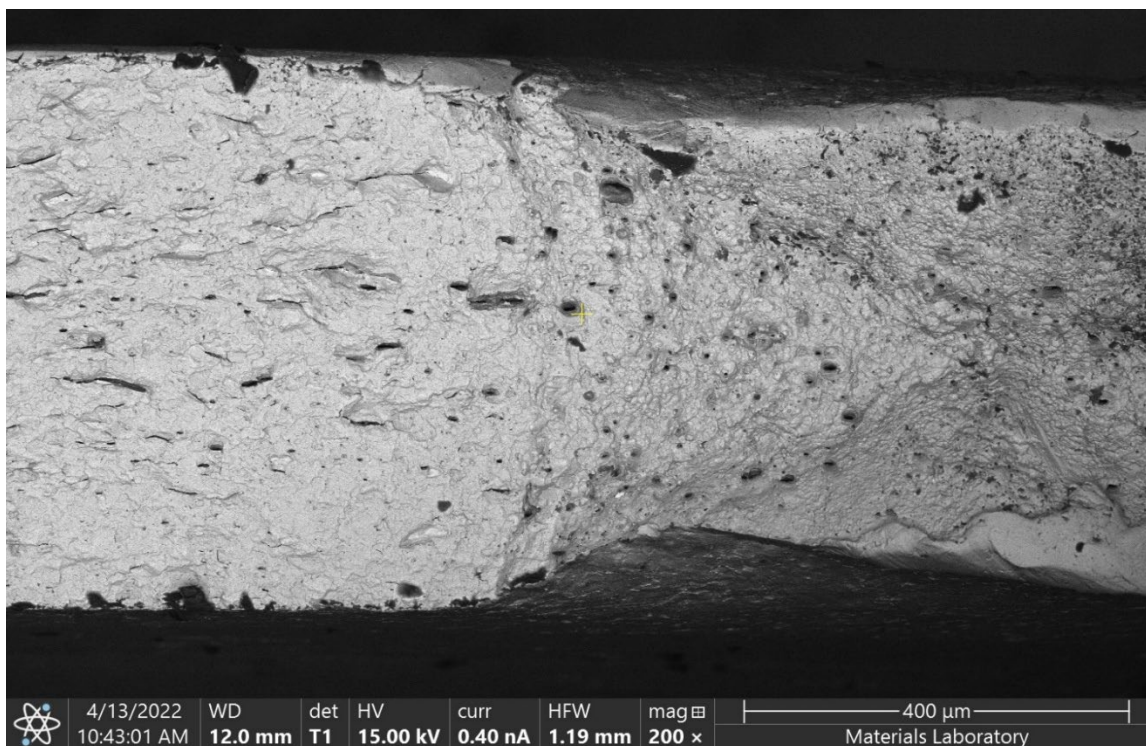


Figure 21 – Backscattered electron (BE) micrograph of the transition from fatigue to overstress fracture of a TT strap.

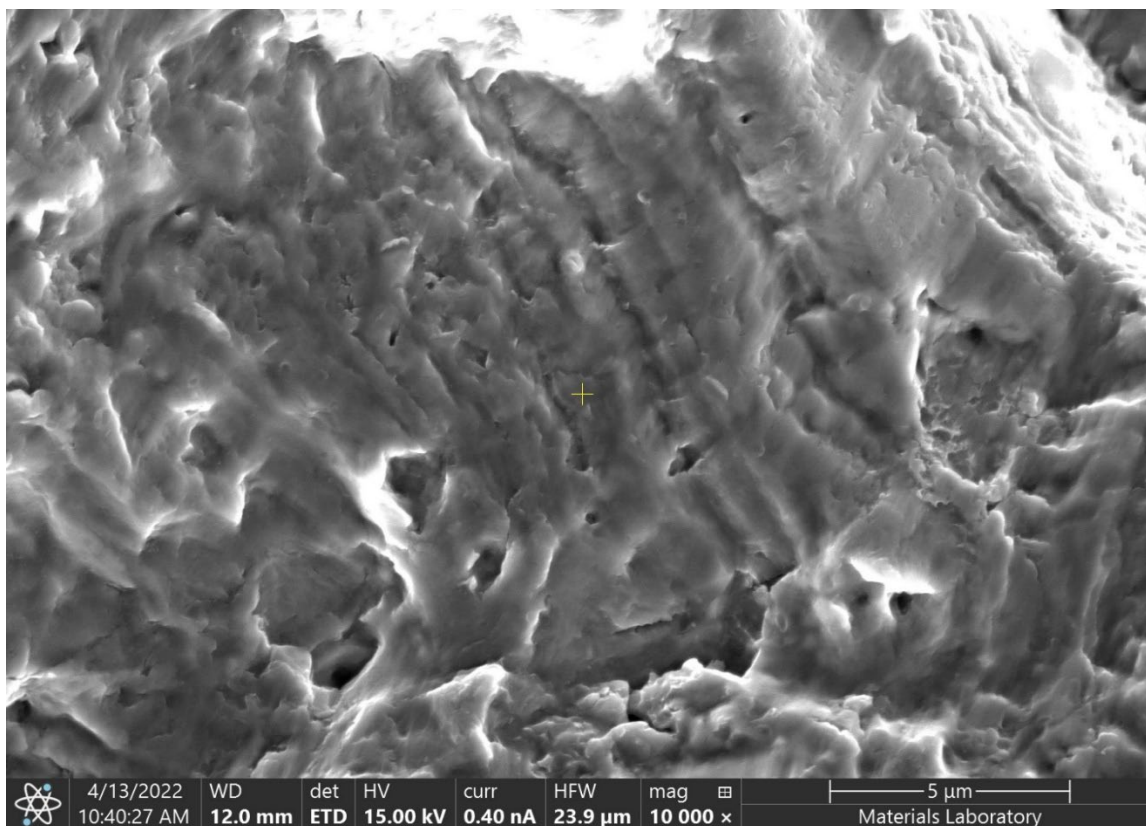


Figure 22 – SE micrograph of striations on the fatigue region of the TT strap.

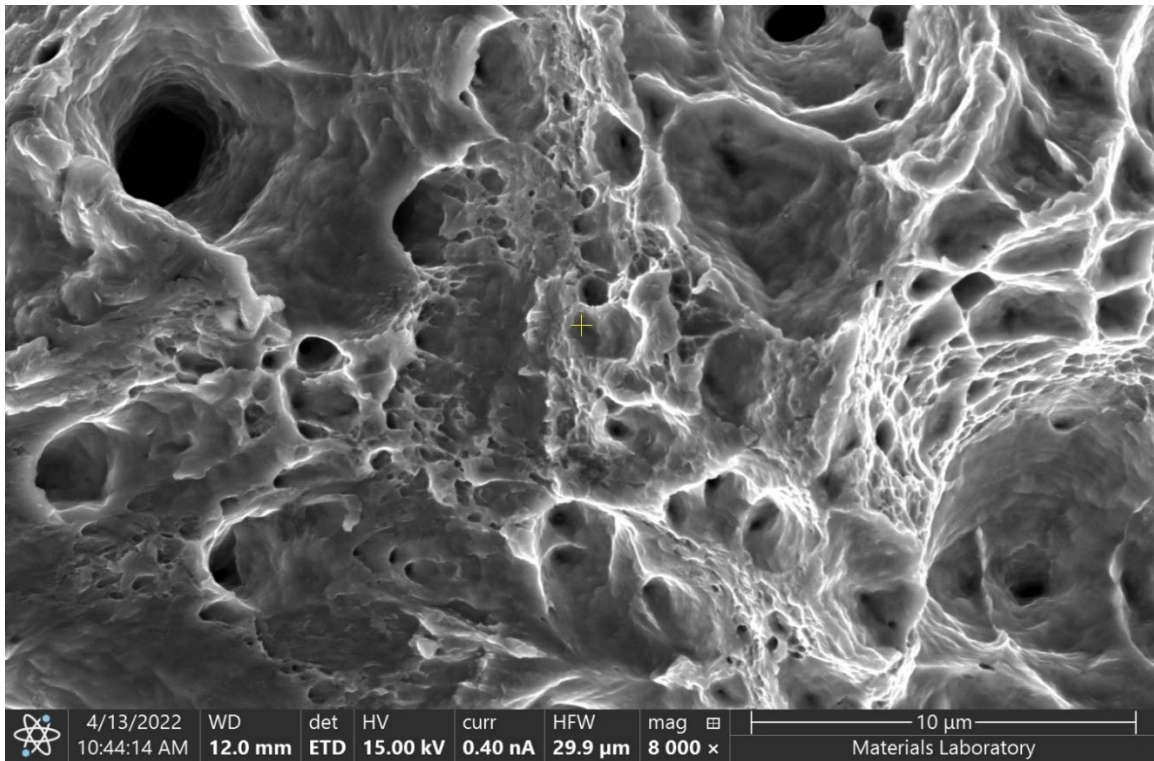


Figure 23 – SE micrograph of dimpled rupture in the overstress region of the TT strap.

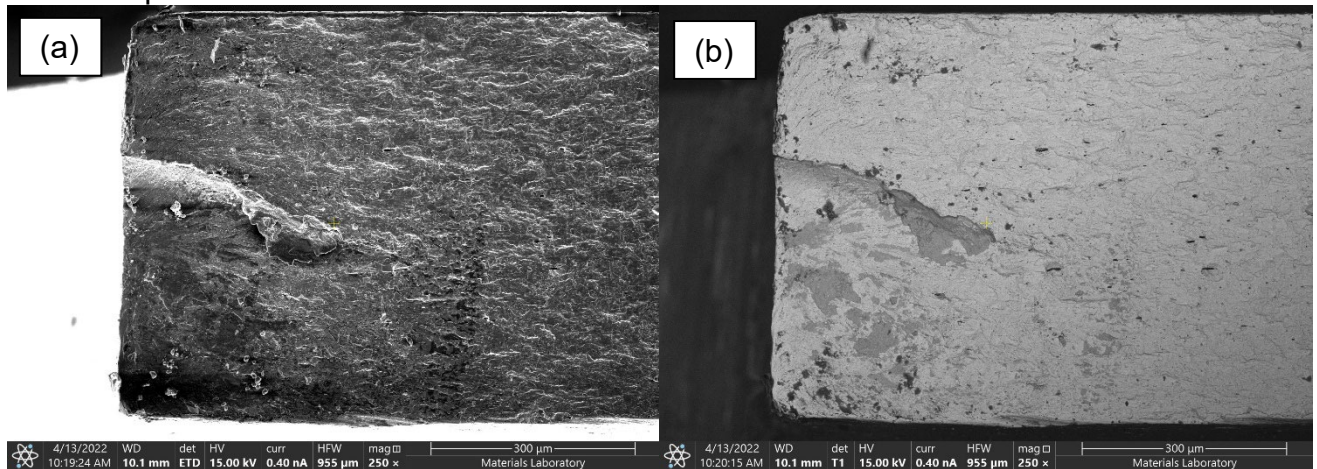


Figure 24 – Views of the fatigue crack initiation sites of a TT strap in (a) secondary and (b) backscattered views.

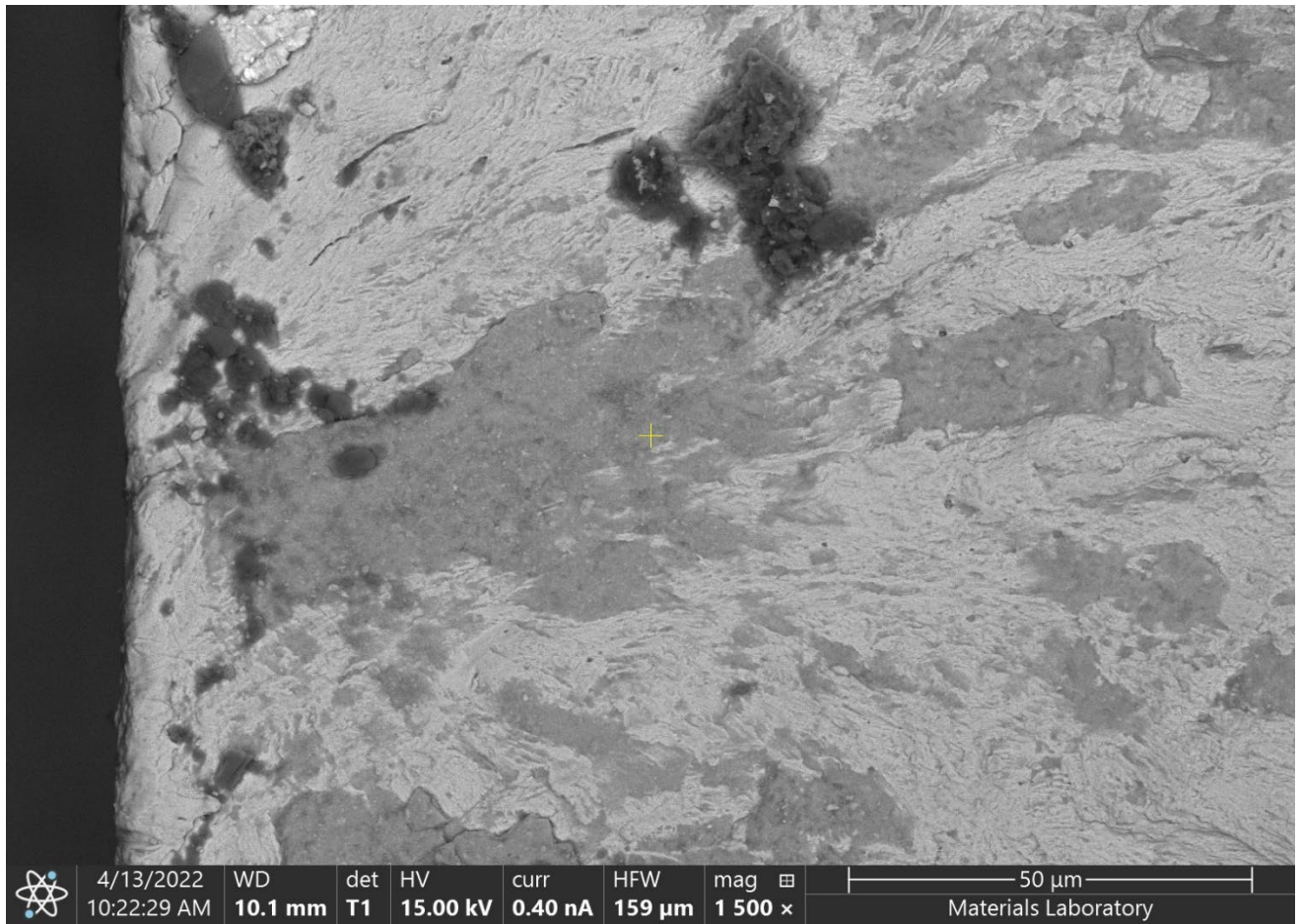


Figure 25 – BE micrograph of a closer view of the primary (larger) fatigue crack initiation site on the TT strap.



Figure 26 – BE micrograph of an angled view of the crack initiation sites.

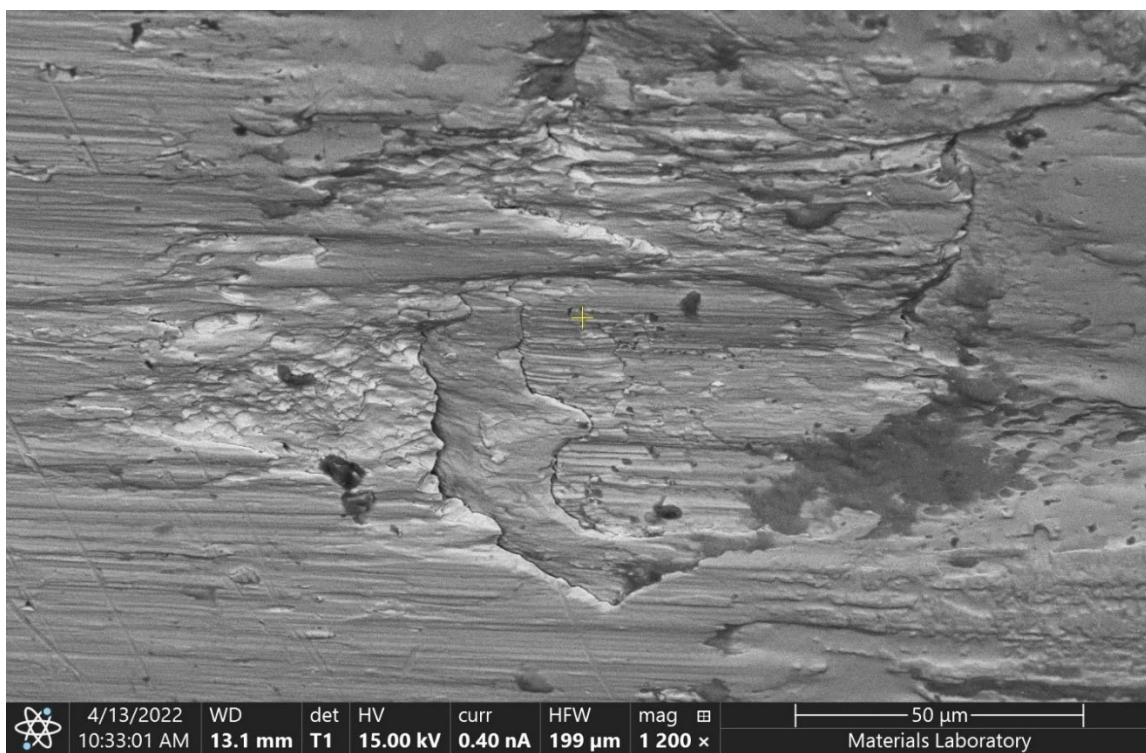


Figure 27 – BE micrograph of wear, spalling, and dissimilar material along the bore of the TT strap.

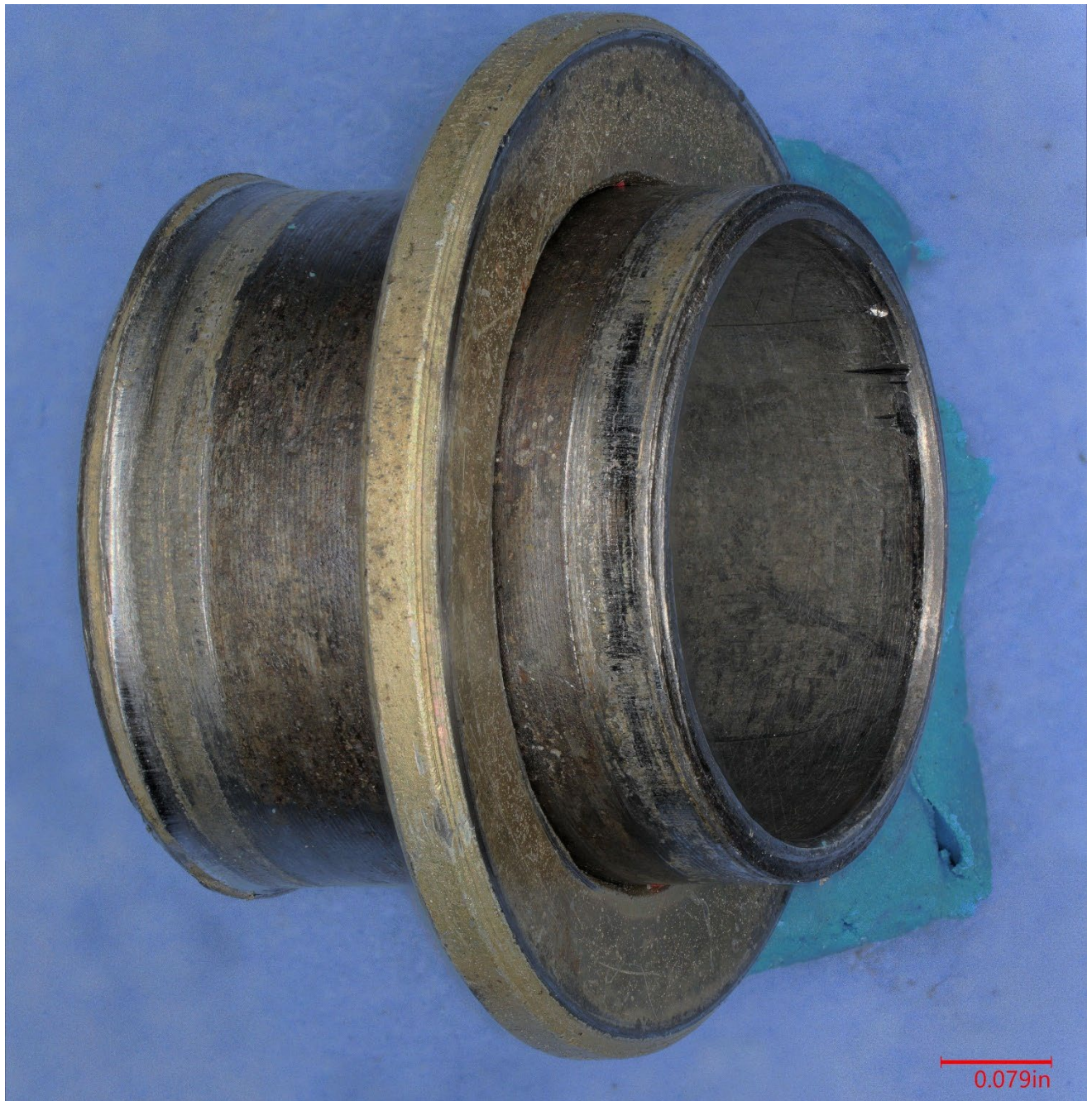


Figure 28 – View of the bearing and a washer from the fractured TT strap bundle.

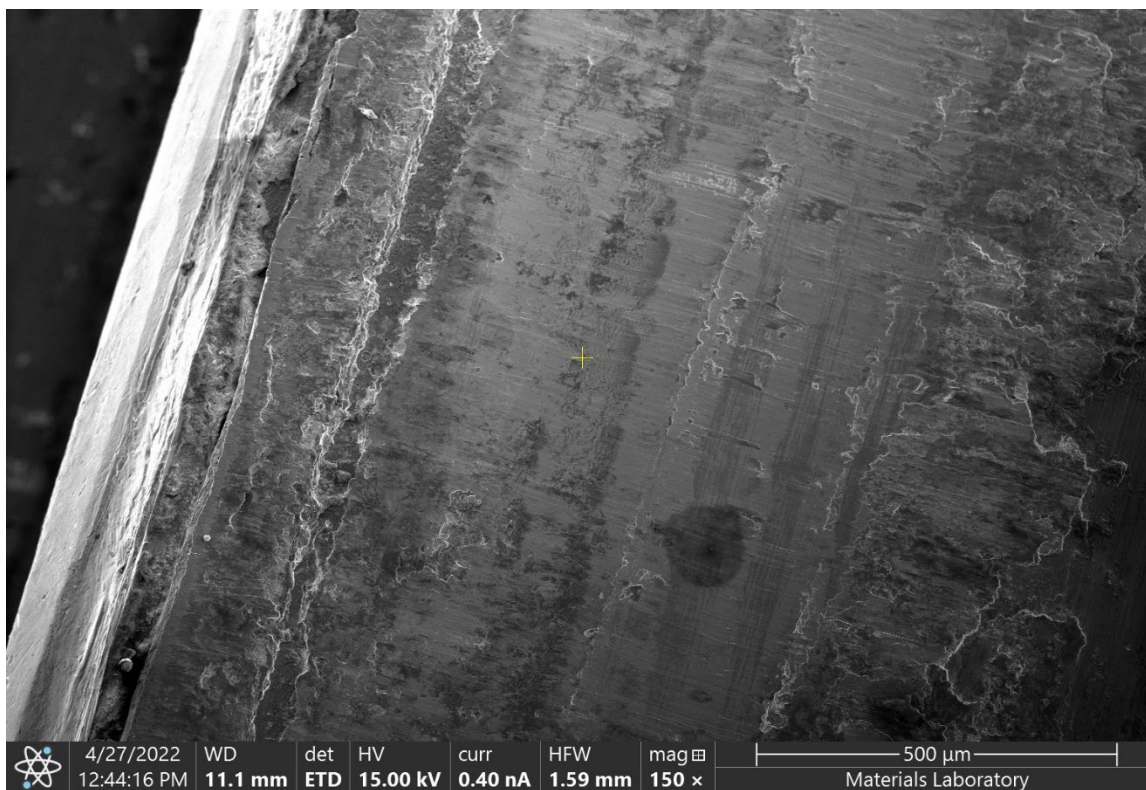


Figure 29 – SE micrograph of the bearing surface near an edge, showing longitudinal wear and smearing.

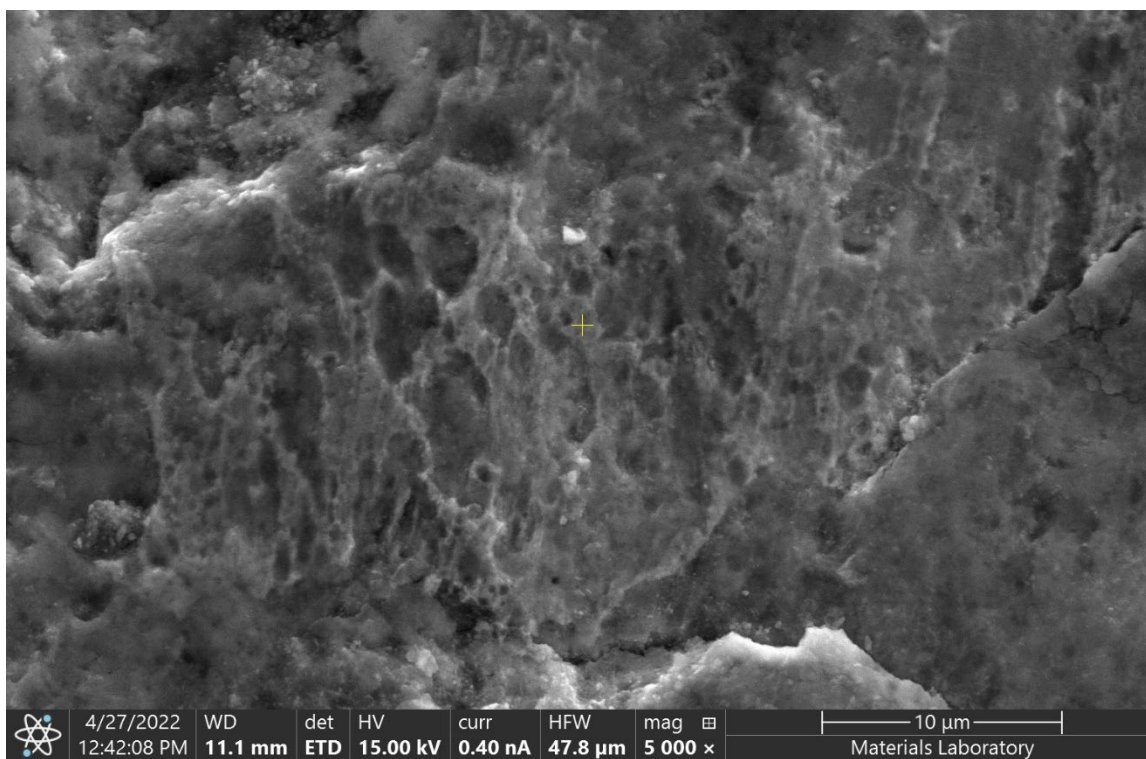


Figure 30 – SE micrograph of localized dimpled rupture in a spalled area of the bearing surface.

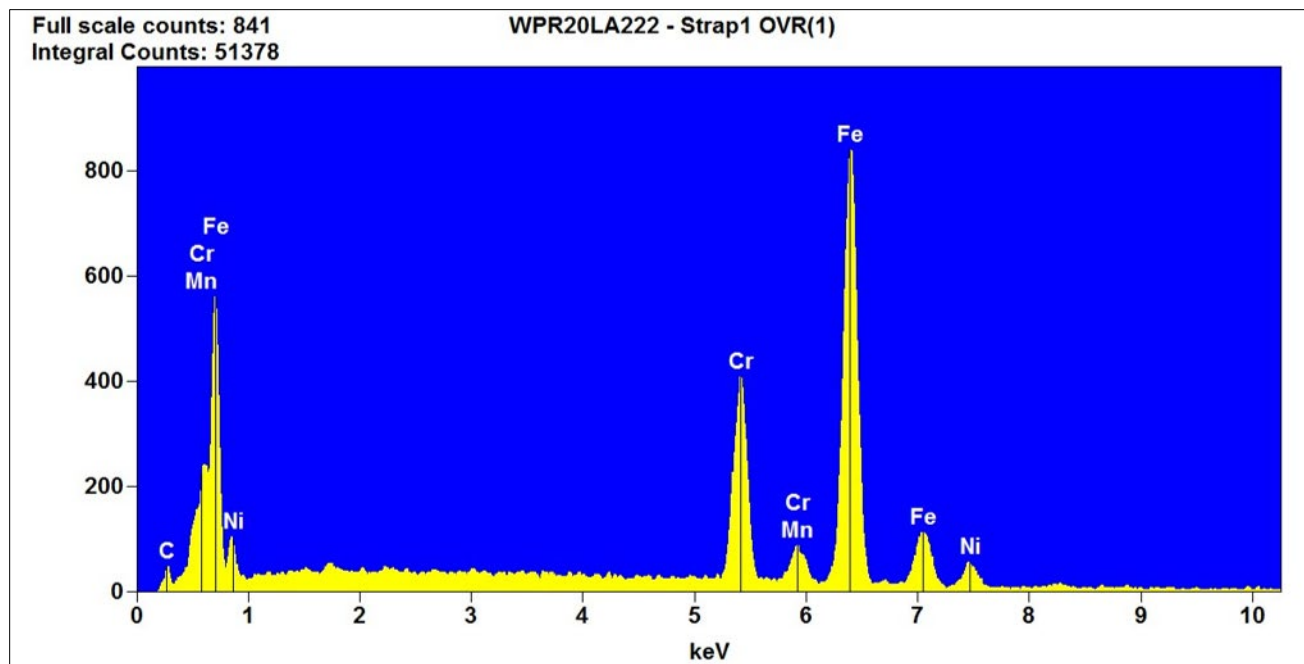


Figure 31 – EDS spectrum of a typical area of the sectioned TT strap.

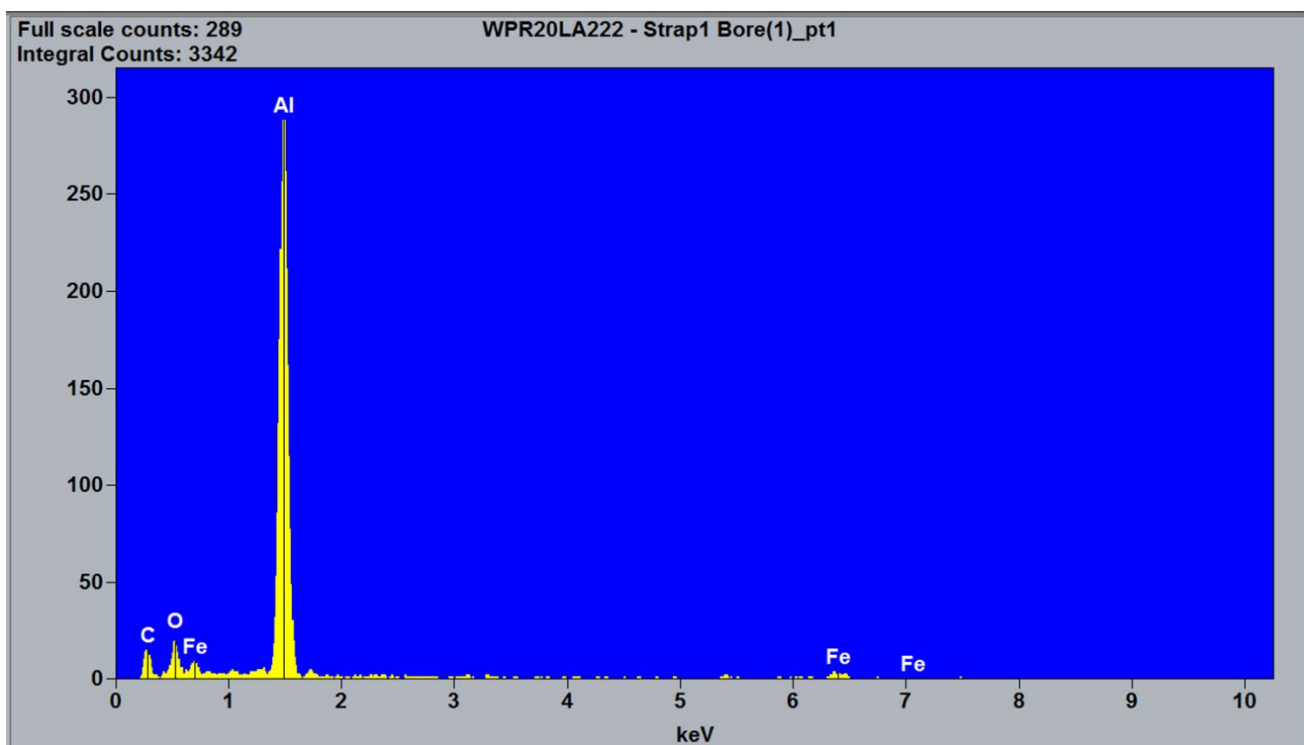


Figure 32 – EDS spectrum of the dissimilar material on the fractured TT strap bore in Figure 27.



Figure 33 – View of the tail rotor gear box assembly, as received.

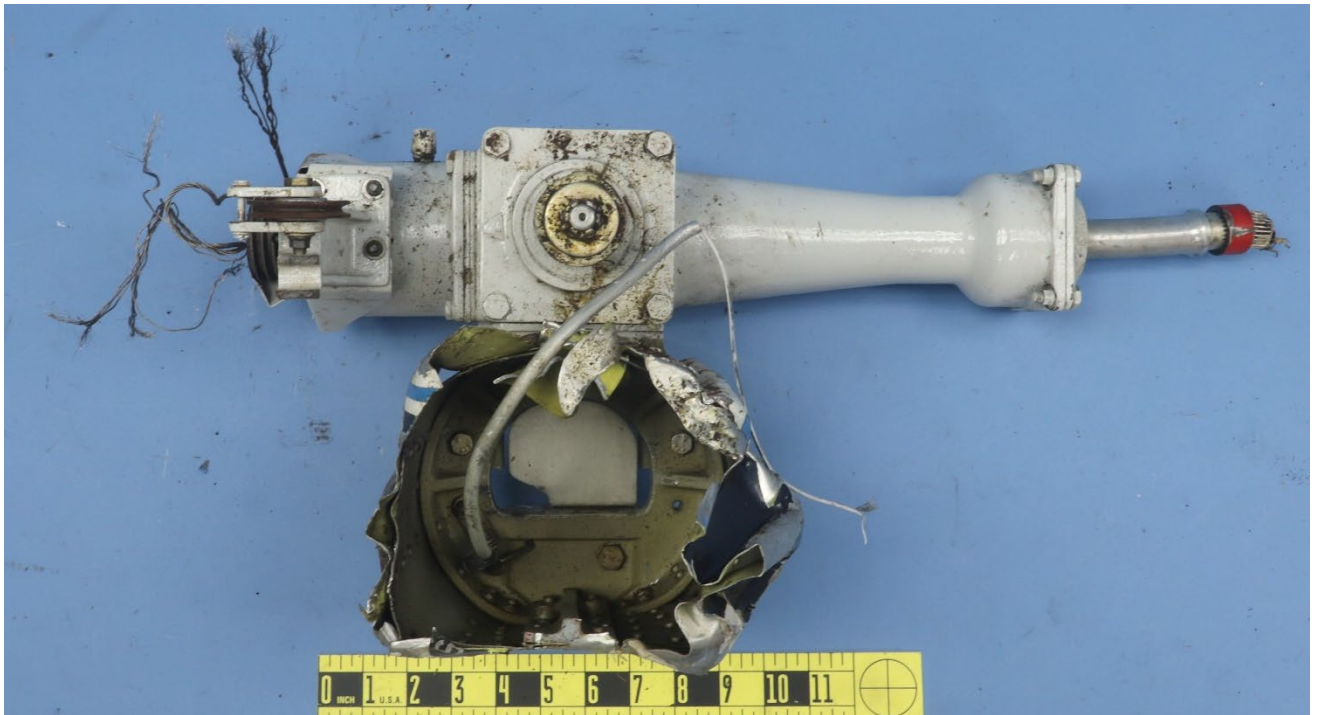


Figure 34 – View of the fractured areas of the tail rotor gear box assembly.