

NATIONAL TRANSPORTATION SAFETY BOARD

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



February 28, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-041

1. ACCIDENT INFORMATION

Place : Houston, Texas
Date : May 2, 2020
Vehicle : MD Helicopters 369E, N8375F
NTSB No. : CEN20LA167
Investigator : Chihoon Shin, AS-40

2. COMPONENTS EXAMINED

Remnants of a tail rotor drive shaft

3. DETAILS OF THE EXAMINATION

On May 2, 2020, about 0203 central daylight time, an MD 369E helicopter was destroyed when it was involved in an accident near Houston, TX. The pilot sustained serious injuries and the other crewmember sustained fatal injuries. A Federal Aviation Administration (FAA) inspector examined and documented the wreckage site where the helicopter had impacted an unoccupied building and terrain. The wreckage was recovered and retained for further detailed examination.

Sections from the fractured tail rotor drive shaft of the helicopter were received by the NTSB Materials Laboratory, as illustrated in Figure 1 and Figure 2. The shaft remnants were generally straight, and still displayed the green primer on the exterior surfaces. The shaft had fractured adjacent to a cylindrical support sheath, located to the right of the fracture in the figures. This sheath had a reflective metallic trait, consistent with having been polished.

Figure 3 shows mating fracture surfaces of the tail rotor drive shaft. The fracture surface was oriented transverse (perpendicular) to the longitudinal direction of the shaft. The fracture surface was generally rough in texture, with no indications of reflective areas. As demonstrated in Figures 3 and 4, the shaft material adjacent to the fracture surface exhibited localized areas with deformation both inward and outward. This deformation was located on one half of the fracture shaft remnants. These deformation features were consistent with compressive buckling.

The opposite side did not exhibit this buckling, but rather localized thinning or necking of material adjacent to the fracture. Figure 6 shows a closer view of this side of the fracture. Some of the outer edges of this fracture area exhibited angled protrusions, consistent with shear lips. These features were consistent with fracture in tension on this side of the shaft.

The opposite side of the fracture, which exhibited compressive buckling, is highlighted in Figure 7. This side of the fracture contained areas with reflective and flattened features—these characteristics were consistent with post-fracture damage such as smearing. This smearing had occurred on the cantilever curl region of the fracture, with shear lips on the outer edge. The outer sheath had also separated from the outer surface of the shaft, which had deformed inward relative to the sheath. In the undamaged region, the fracture surface exhibited a rough, fibrous texture, with a dull gray luster. These features were also present on the opposite side shown in Figure 6.

The section of the fractured shaft with the sheath (shown in Figure 4) was examined using a scanning electron microscope (SEM). Figure 8 shows a typical view of the tension side of the fracture surface. A closer view of this area is shown in Figures 9 and 10. These areas revealed dimpled rupture, consistent with tensile overstress fracture. No other features consistent with other fracture modes were observed in this area.

The compressive side of the fracture surface is illustrated at the edge in Figure 11. This portion of the fracture surface was generally flatter than the tensile side. Figures 12 and 13 show a closer view of the fracture features in this area. As demonstrated in these figures, this area exhibited slanted dimpled rupture, consistent with overstress with a shear component.

The areas of the fracture surface adjacent to the compressive buckling were also examined. One such area is typified in Figure 14. As shown in Figure 15, this portion of the fracture surface exhibited dimpled rupture, consistent with overstress.

The fracture surface areas nearest to the cylindrical support sheath were examined, as illustrated in Figures 16 and 17. Figure 16 shows an area where some compressive buckling had occurred in the shaft. This figure shows fracture of the adhesive between the sheath and outer surface of the shaft. Figure 17 shows an area in the tensile side of the fracture surface. In this figure, the intermediate adhesive had fractured parallel to the shaft fracture surface but was still affixed to both the shaft and the cylindrical sheath.

Figure 18 shows a closer view of the surface of the cylindrical sheath. This surface, while generally reflective and typical of having been polished, exhibited darker parallel wear marks oriented in the circumferential direction of the shaft. These wear marks were consistent with the direction of rotation of the shaft and sheath. There were no indications of gouging or material spalling on this part.

All these features were consistent with fracture of the tail rotor drive shaft from overstress. The perpendicular fracture surface orientation, along with localized

compressive buckling were consistent with torsional overstress with some bending. No indications of pre-existing cracking, such as from fatigue, were observed.

The chemical composition of the shaft was inspected using energy dispersive x-ray spectroscopy (EDS). The composition was consistent with a 6000-series aluminum alloy. The electrical conductivity was examined per ASTM E1004.¹ The conductivity averaged 46.5 %IACS. The hardness was tested per ASTM E18.² The hardness averaged 51 HRBW.³ Per AMS 2658, these data were consistent with a T6 heat-treated condition for this class of alloys.⁴

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¹ ASTM E1004 – *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. ASTM International, West Conshohocken, PA

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

³ HRBW – Hardness, Rockwell B scale. An indentation method of determining the hardness of softer metals using a 1/16-inch diameter tungsten ball indenter and 100 kg major load.

⁴ AMS 2658 – *Hardness and Conductivity Inspection of Wrought Aluminum Alloy Parts*. SAE International, Warrendale, PA.

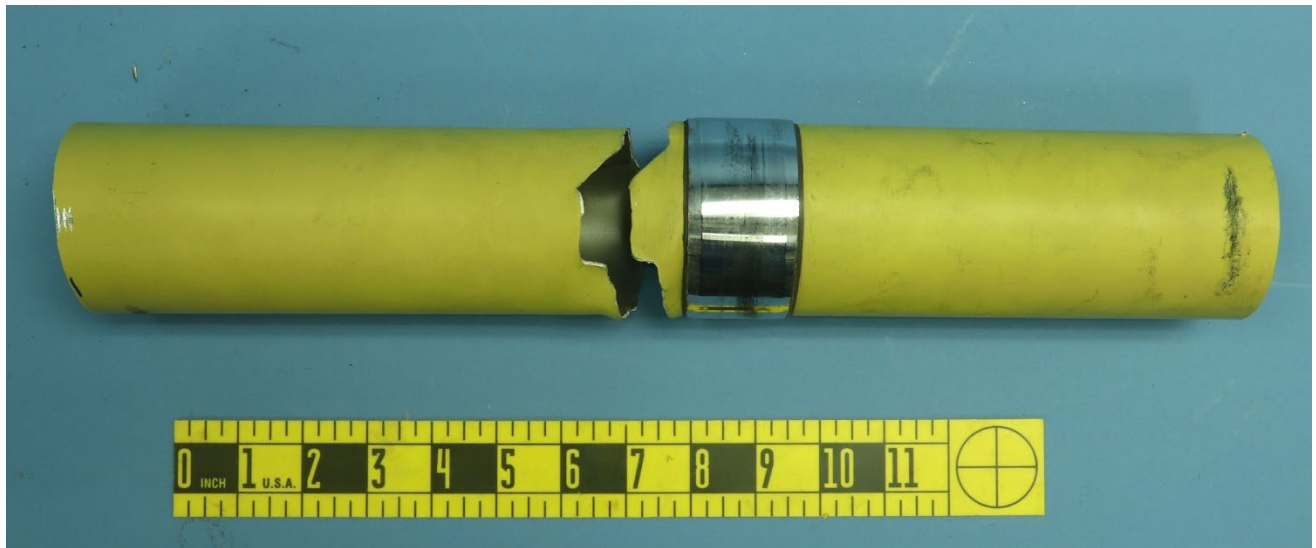


Figure 1 – The fractured tail rotor drive shaft sections, as received.

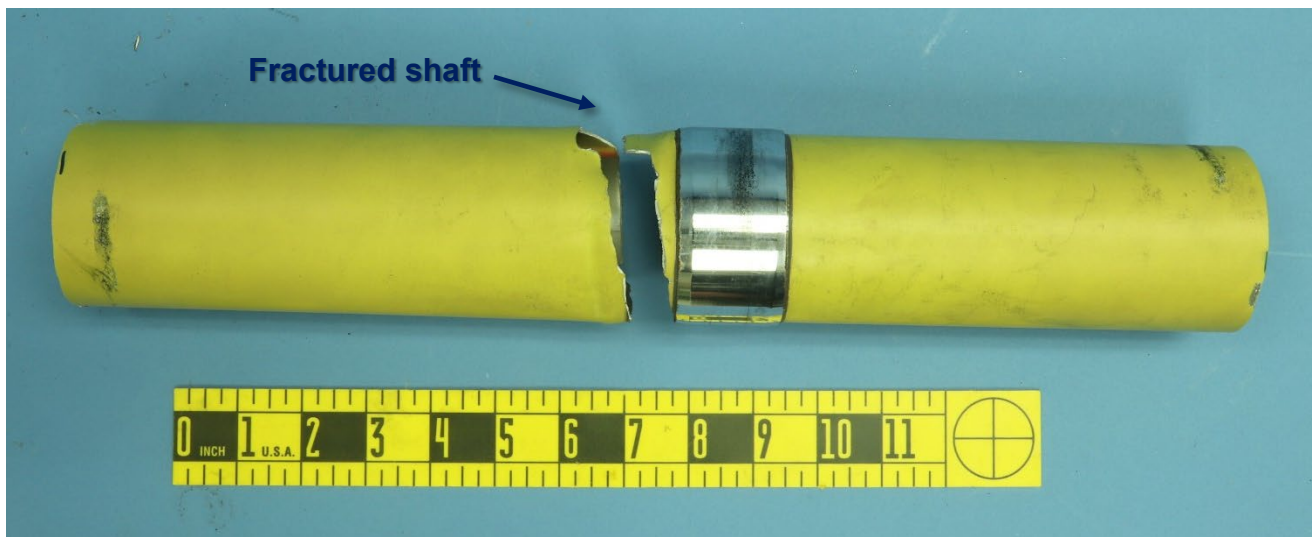


Figure 2 – The fractured tail rotor drive shaft sections from Figure 1, rotated 90° to show a side view.

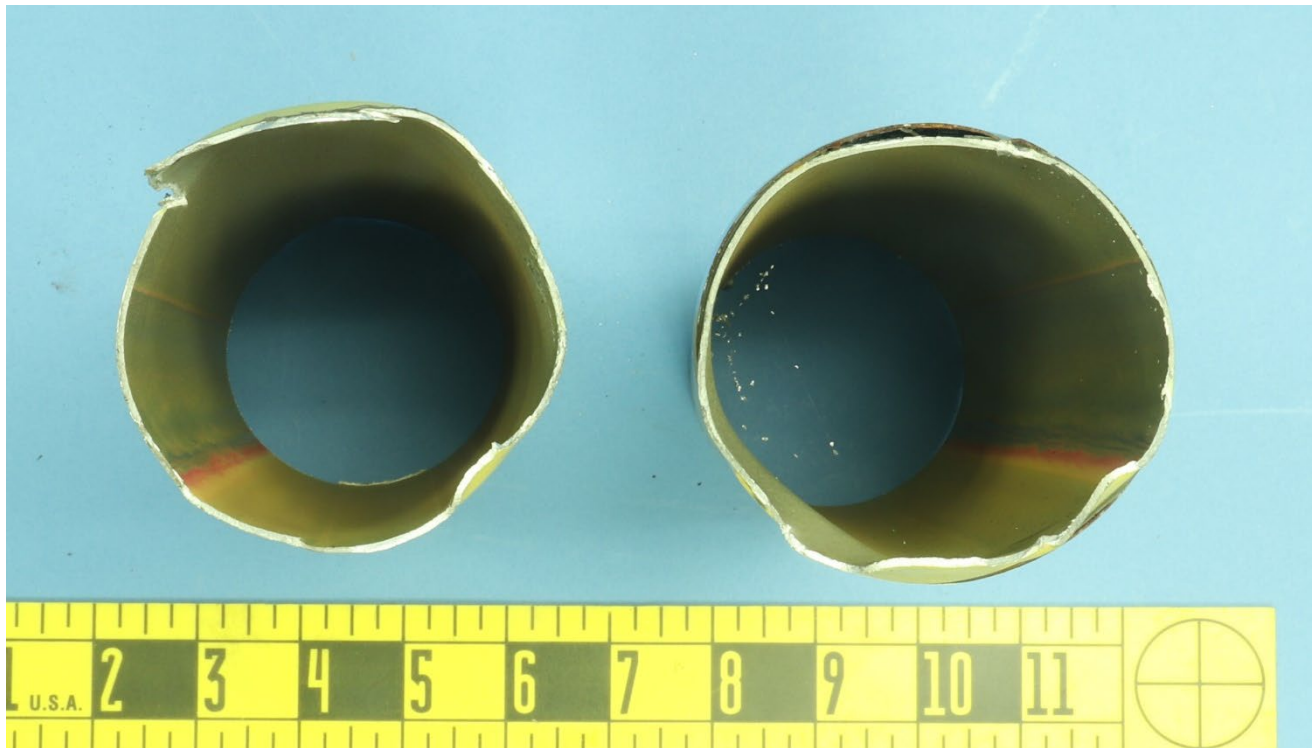


Figure 3 – View of the mating fracture surfaces of the tail rotor drive shaft sections.

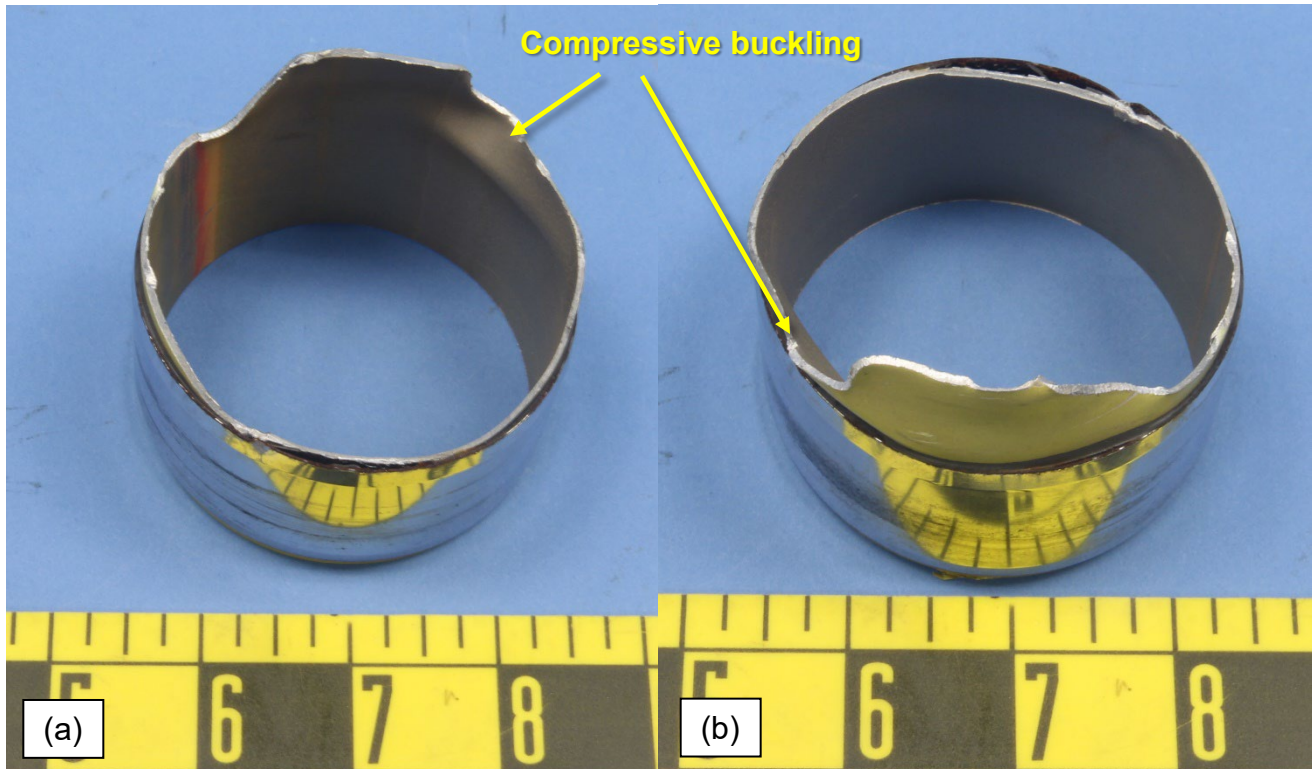


Figure 4 – View of the sectioned end of the fractured shaft from the side with the support ring. The areas of compressive buckling are annotated (arrows).

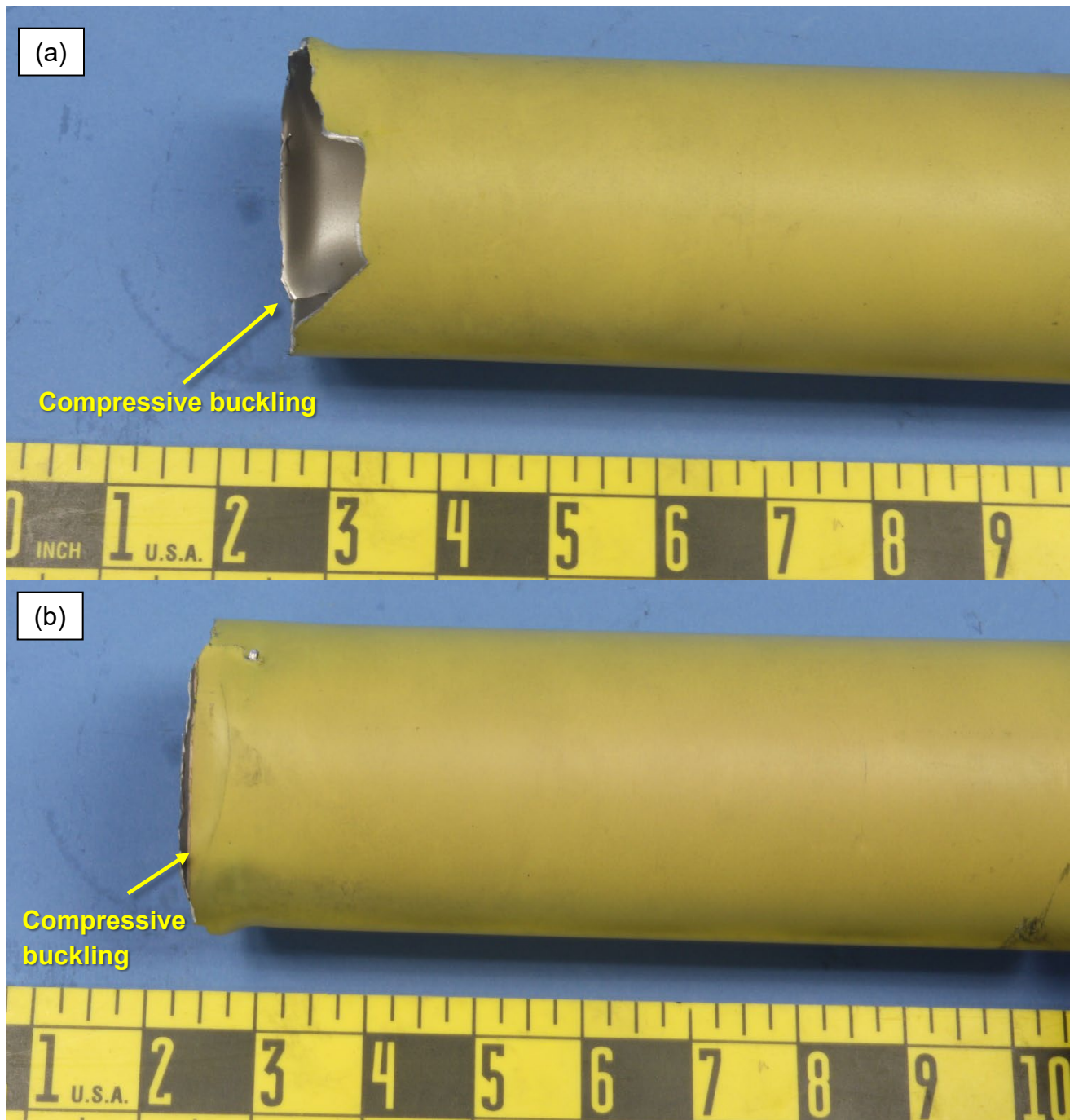


Figure 5 – View of the mating fracture surface to Figure 4. The areas of compressive buckling are annotated (arrows).

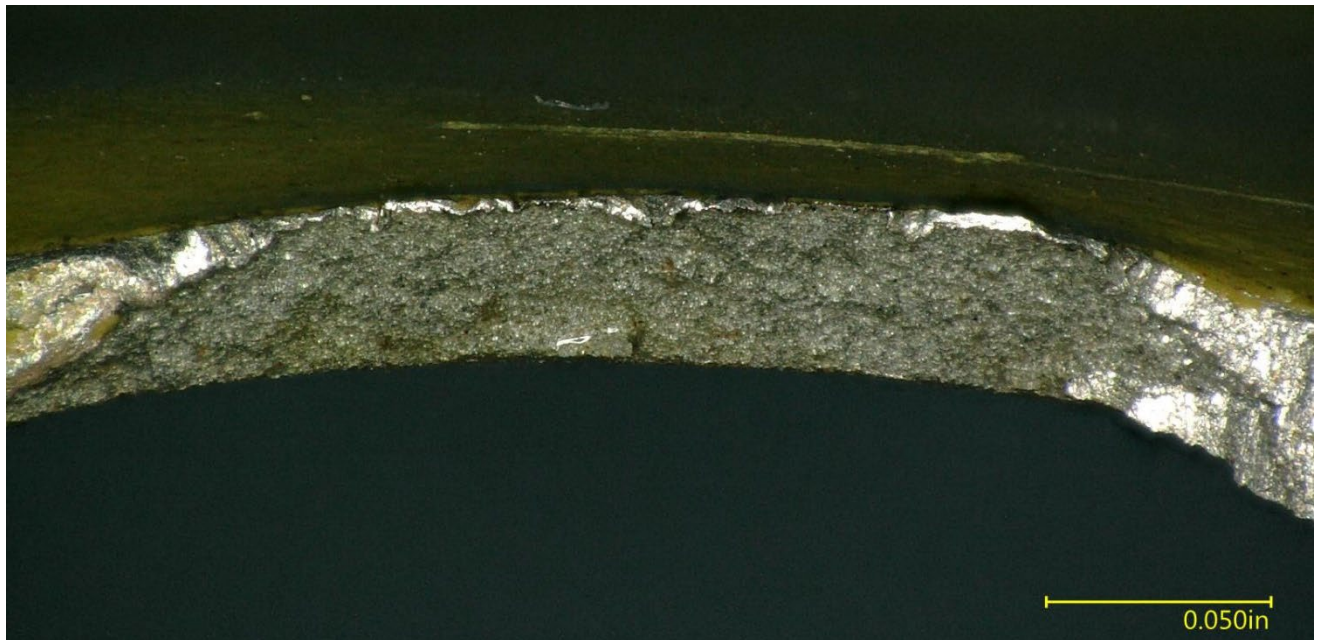


Figure 6 – View of the fracture surface from the tension side.

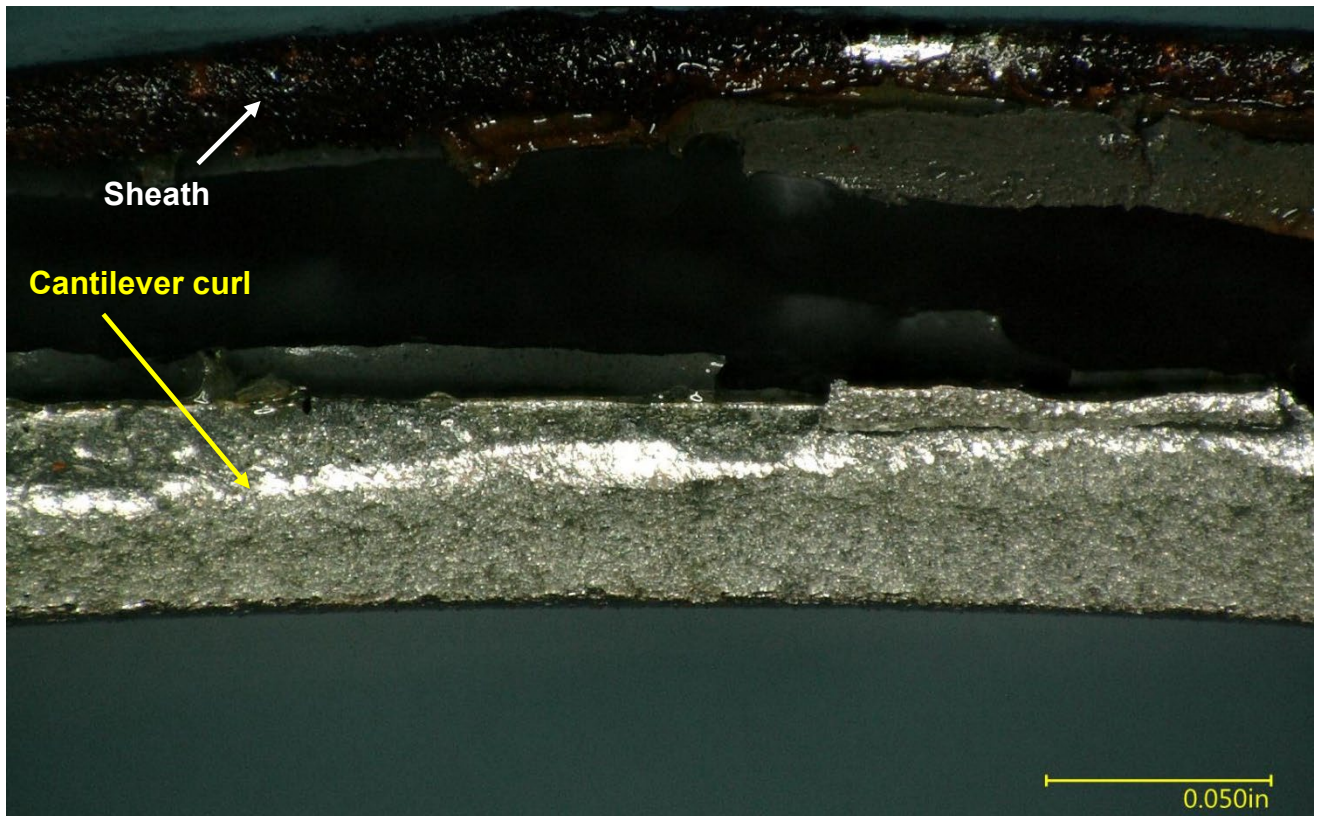


Figure 7 – View of the fracture surface from the compression side, showing the sheath separated from the outer surface.

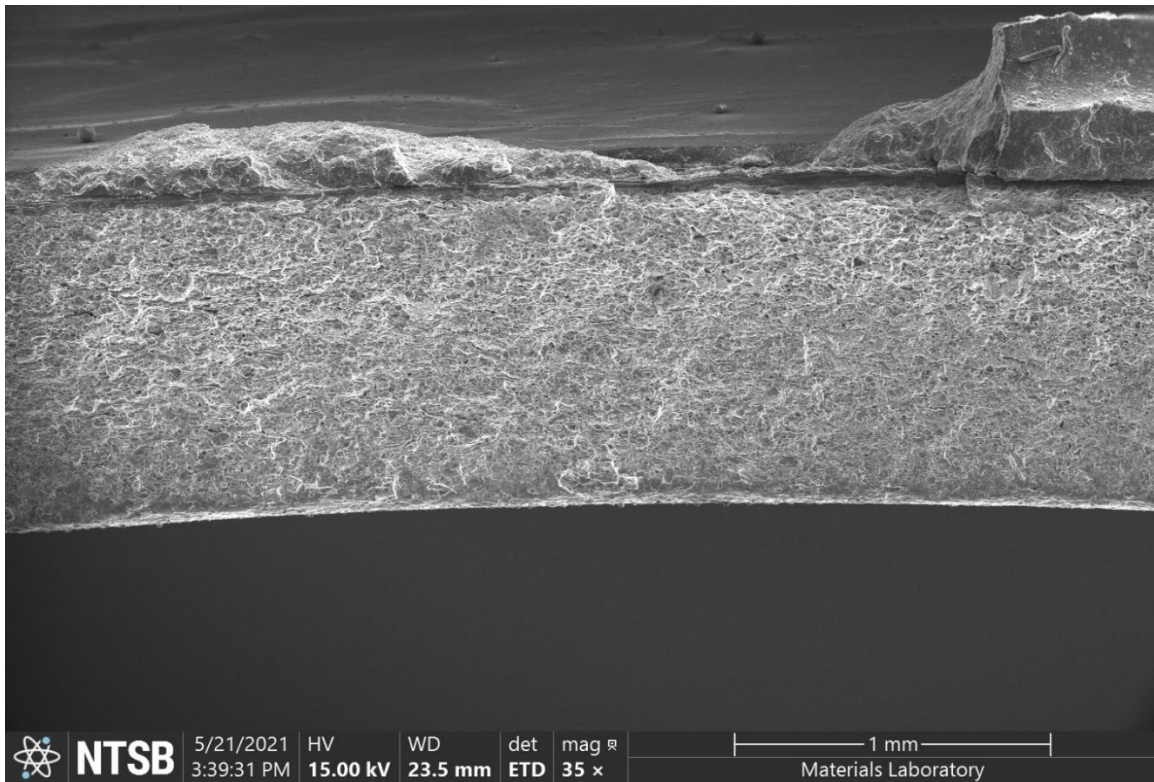


Figure 8 – Secondary electron (SE) micrograph of the tension side region of the fracture surface.

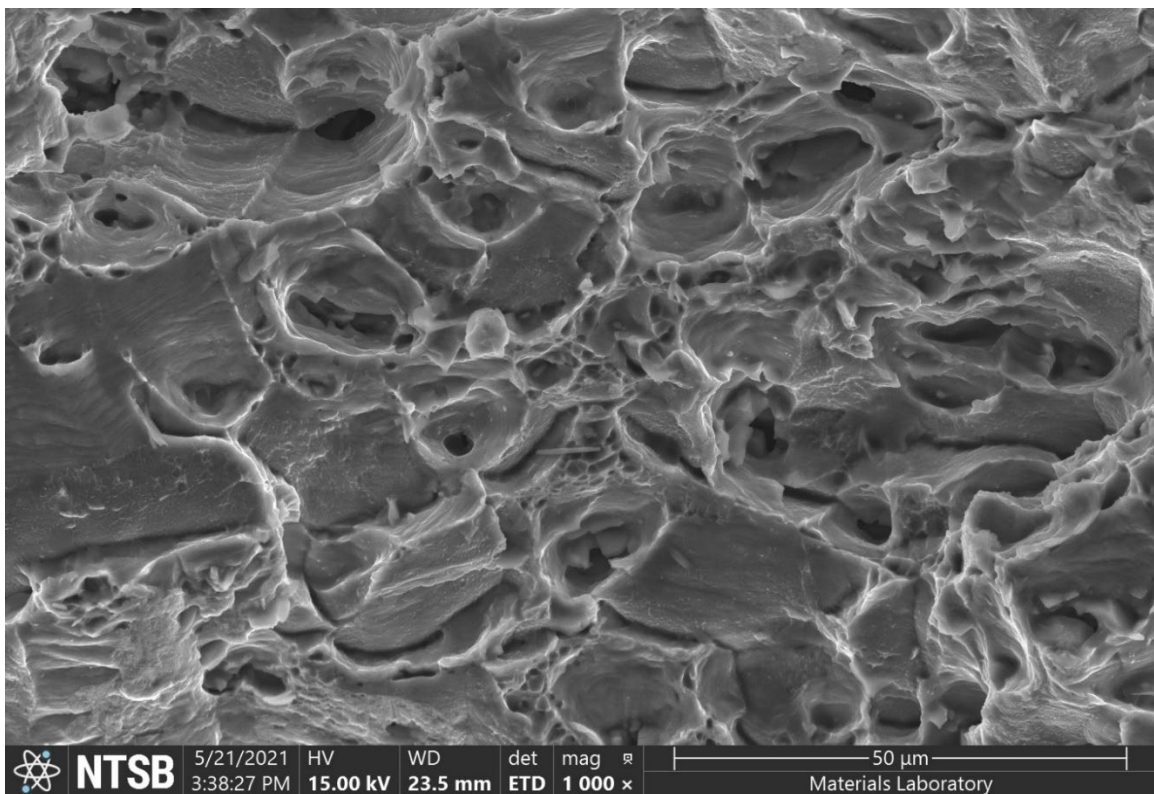


Figure 9 – SE micrograph of the dimple rupture on the tension side fracture.

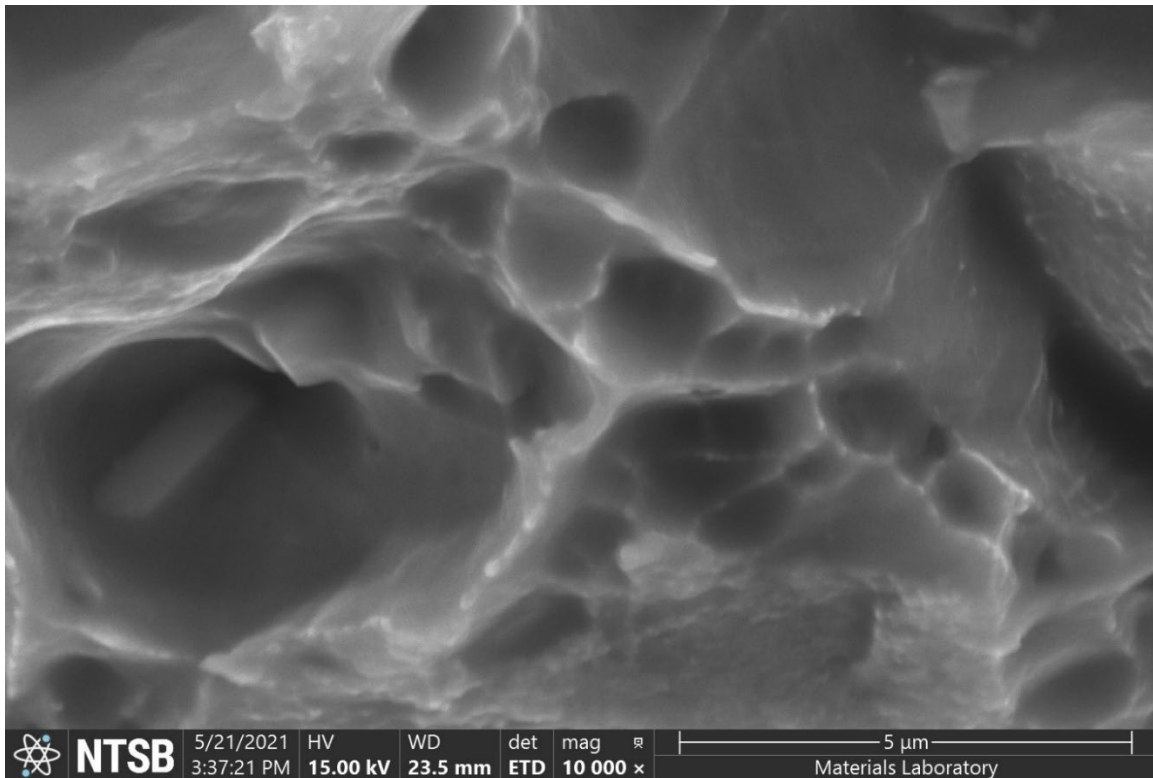


Figure 10 – SE micrograph of a closer view of the dimpled rupture in Figure 9.

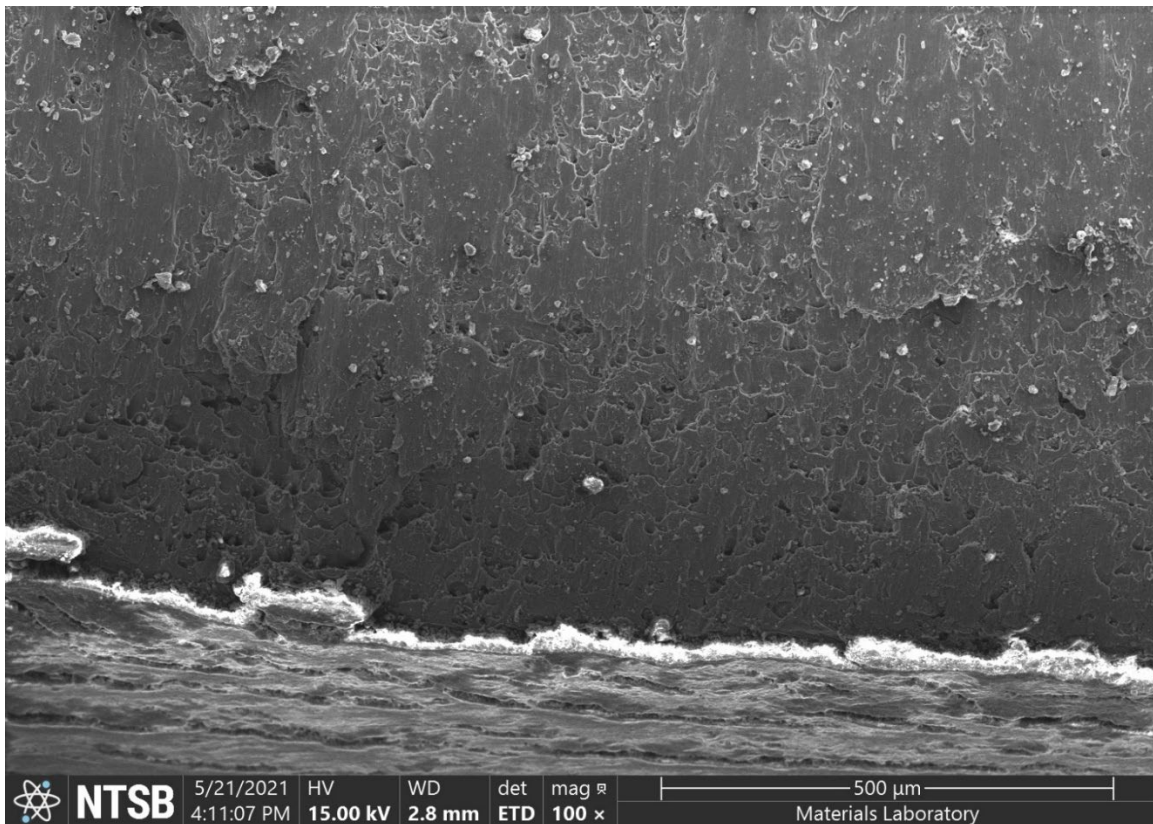


Figure 11 – SE micrograph of the edge of the compression side of the fracture.

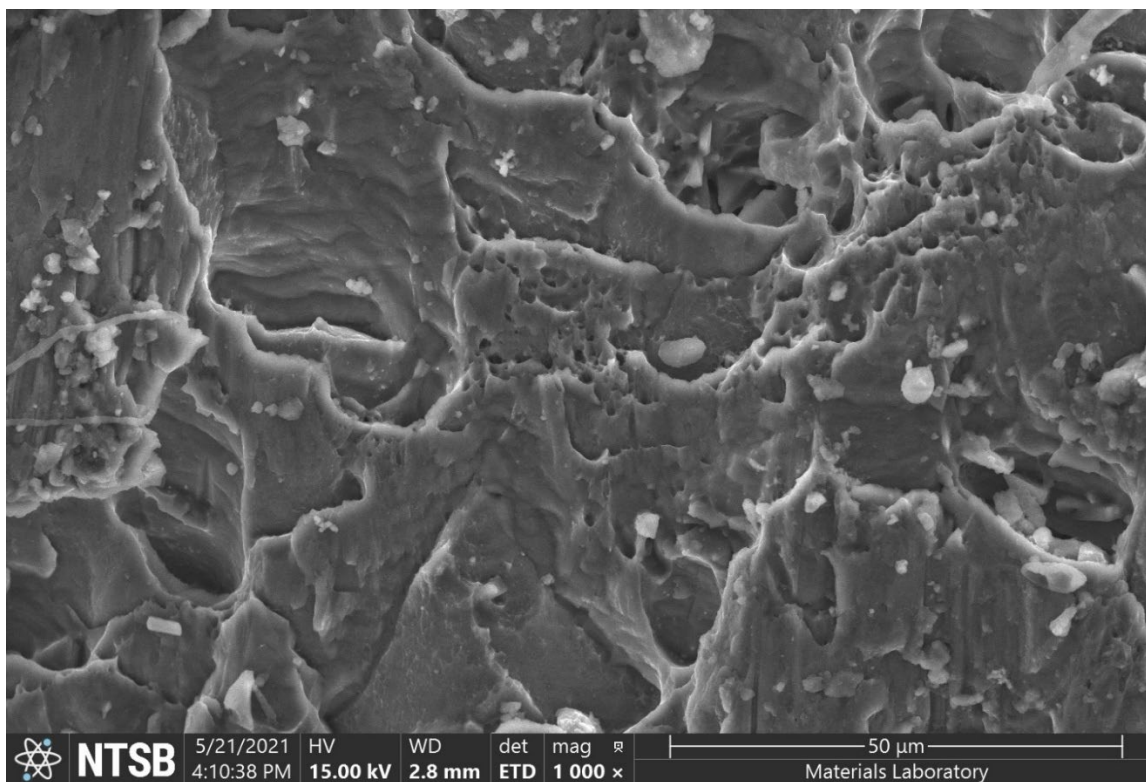


Figure 12 – SE micrograph of dimpled rupture from the compressive fracture area.

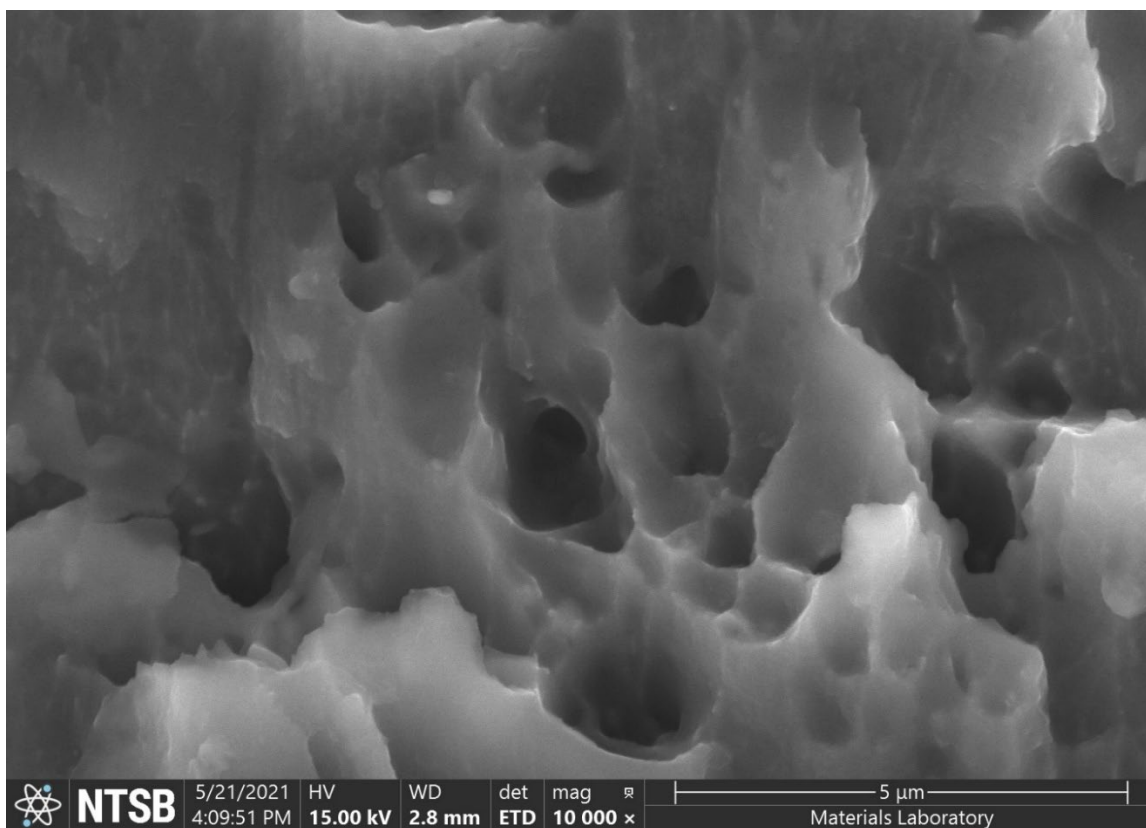


Figure 13 – SE micrograph of shear dimpled rupture from Figure 12.

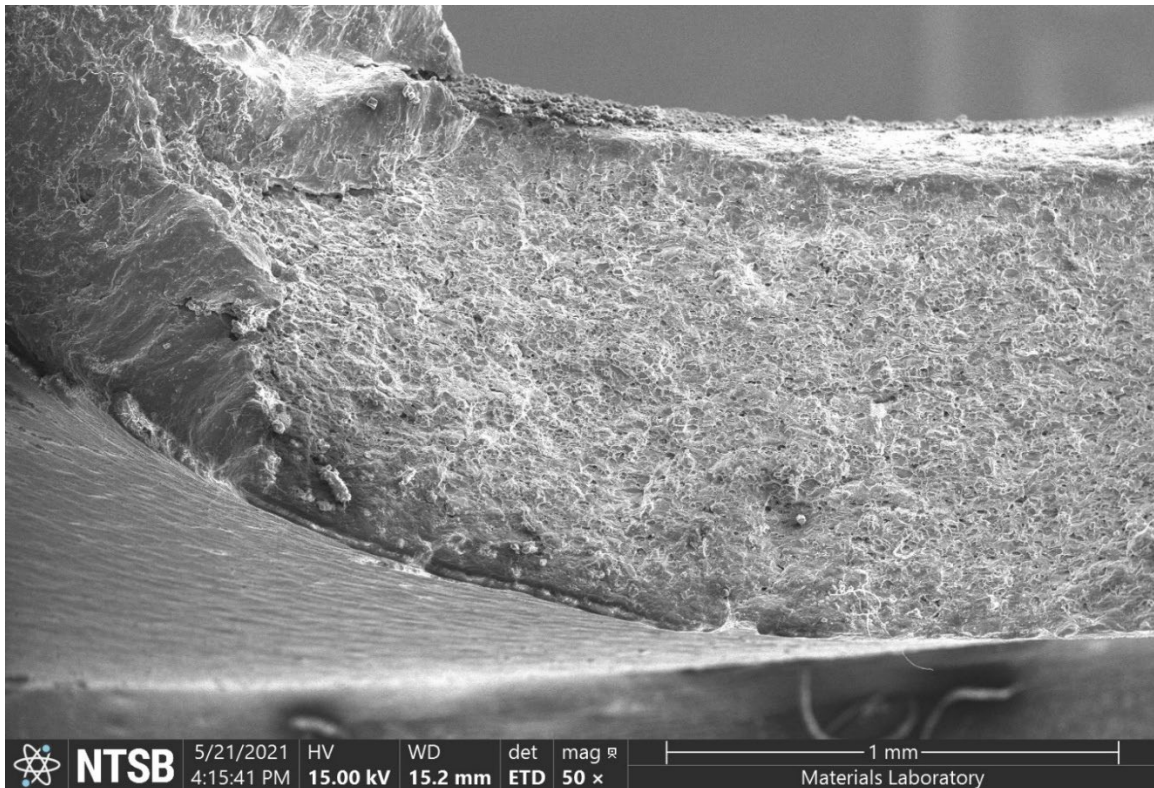


Figure 14 – SE micrograph of the fracture surface on the compressive side adjacent the buckled area.

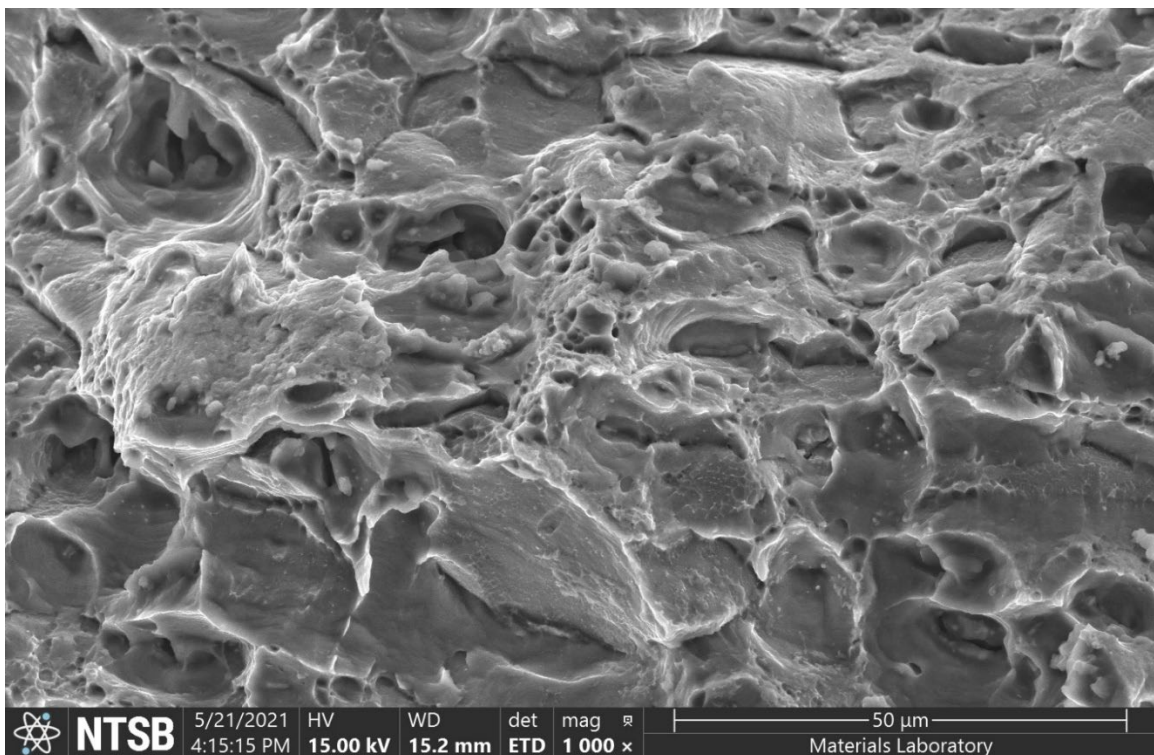


Figure 15 – SE micrograph of dimpled rupture in the area in Figure 14.

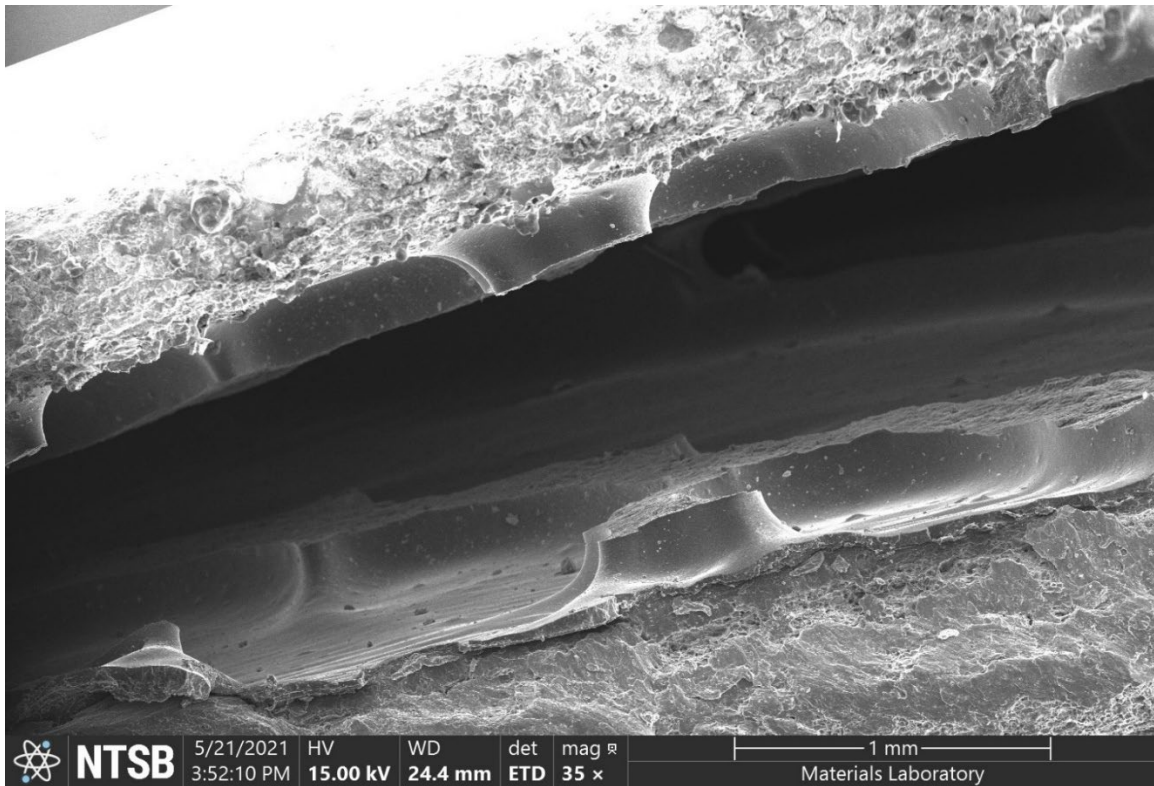


Figure 16 – SE micrograph of the fractured adhesive between the cylindrical outer sheath and the fractured shaft on the compressive side.



Figure 17 – SE micrograph of the fractured adhesive between the cylindrical outer sheath and the fractured shaft on the compressive side.

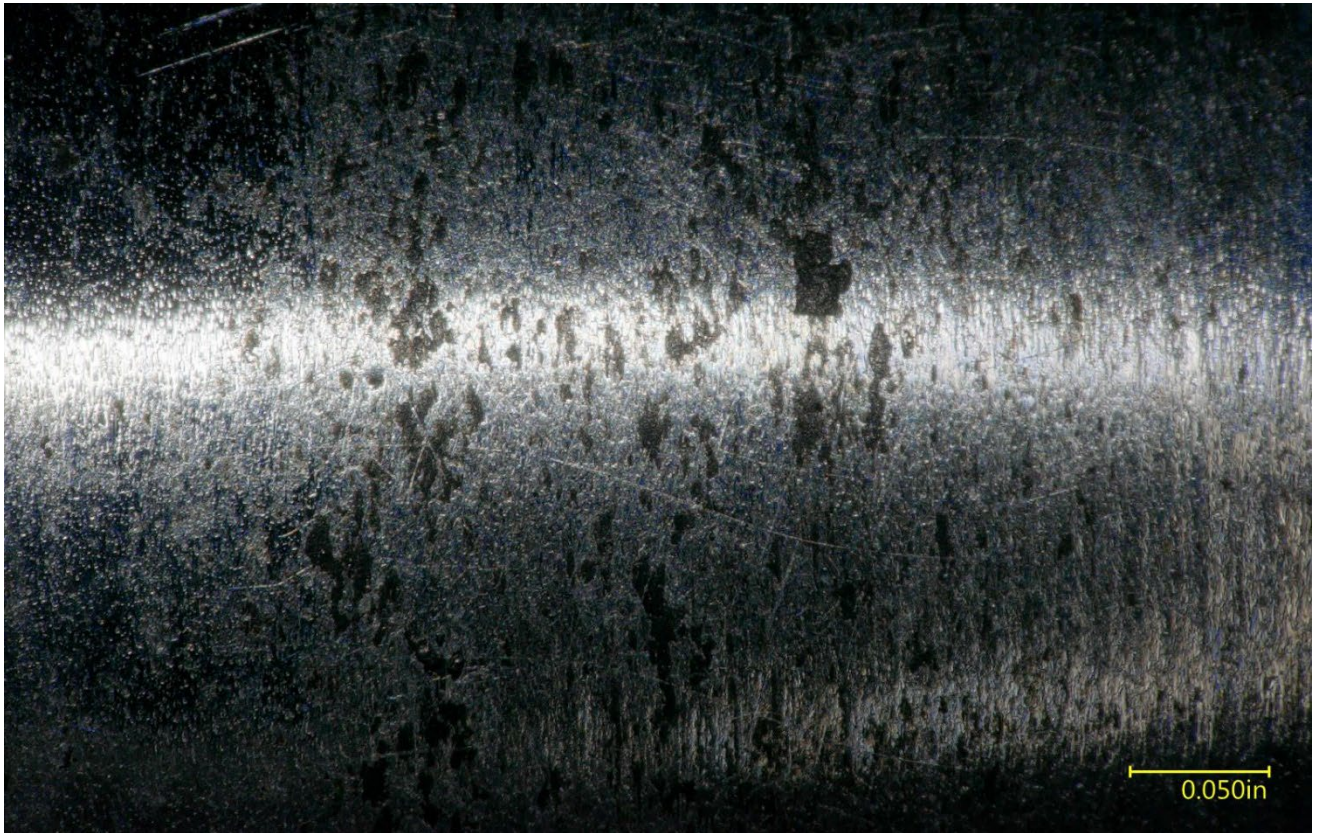


Figure 18 – Wear marks on the outer shaft sheath.