

NATIONAL TRANSPORTATION SAFETY BOARD

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



September 7, 2021

MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-064

1. ACCIDENT INFORMATION

Place : Ogallala, Nebraska
Date : August 24, 2020
Vehicle : Grumman G-146B Ag Cat, N2437D
NTSB No. : CEN20LA364
Investigator : Craig Hatch, AS-CEN

2. COMPONENTS EXAMINED

Remnants of a connecting rod

3. DETAILS OF THE EXAMINATION

On August 24, 2020, about 1550 mountain daylight time, a Grumman G-164B airplane sustained substantial damage when it was involved in an accident near Ogallala, NE. The commercial pilot was uninjured. According to initial information, the engine lost power after takeoff during the climb. The pilot made an emergency landing in a cornfield about 1.8 miles from the airport where the airplane came to rest in an inverted position. The remnant of a connecting rod from the Pratt & Whitney R-1340-S1H1-G reciprocating engine was sent to the NTSB Materials Laboratory for further examination.¹

Figure 1 shows the connecting rod remnant, as received, from the side showing the web and oriented to show one of the flange faces. The remnant comprised only the upper 5 inches of the section that had connected to the piston pin. The pin hole bore had fractured and deformed inward, as illustrated in Figure 1a. Besides deformation of the pin connection, the rod exhibited deformation in multiple directions, consistent with indications of tension, bending, and torsion or twisting.

Figure 2 shows the fracture surface, viewed as received. The orientation of the fracture surface was perpendicular to the longitudinal direction of the rod, shown in Figure 1. The Figure 2 view of the fracture surface demonstrates some of the plastic deformation of the part, with both flanges and the web exhibiting indications of deformation. The ends

¹ The R-1340 Wasp, the Pratt & Whitney aircraft company's first engine, was a single-row, nine-cylinder, air-cooled, radial reciprocating engine. This model displaced 1,344 cubic inches (22 L) at 600 hp (450 kW), and was manufactured by Pratt & Whitney, headquartered in East Hartford, CT.

of the flanges on the right side of the figure exhibit crushing inward, whereas the flange ends on the opposite side were flared outward. In addition, the web was bent away from the crushed flanged edge, consistent with bending and compression towards the right side of the figure.

The end of the fracture surface was sectioned from the rod remnant and is shown post-sectioning after cleaning with acetone in Figure 3. Much of the fracture surface exhibited a surface brown-rust color, consistent with post-fracture oxidation. Most of the fracture surface exhibited a rough, fibrous texture with a dull luster. The web area exhibited an approximate 45° slanted fracture orientation, and the lower flange area in Figure 3 exhibited a mottled, reflective appearance. The features on the lower flange in Figure 3 were consistent with post-fracture smearing and batter.

The upper flange sectioned fracture surface in Figure 3 is highlighted in Figure 4. An initial visual examination of this flange appeared to exhibit distinct fracture regions. However, after cleaning in an ultrasonic bath with an Evapo-Rust® solution, the fracture surface exhibited more uniform features, illustrated in Figure 5.² This flange exhibited slanted orientations on the ends, with stepped and angled levels along the center above the web. The centermost upper areas in Figure 5 were more reflective than the surrounding areas.

The upper face of the flange is illustrated in Figure 6. This demonstrated that the centermost area was recessed with respect to the ends of the flange. Further, there were parallel cracks next to the fracture surface particularly along the centerline. This area had been plastically deformed upward, as illustrated in Figure 7, the side view. These features were consistent with upward bending and local compression on the upper flange face. The side view in Figure 7 also demonstrated the angled orientation of the fracture surface along the web.

The fracture surface was examined using a scanning electron microscope (SEM). Figure 8 shows an area towards the right of the center reflective region shown in Figure 5. This area showed a flatter morphology than the protruding area to the right and exhibited features reminiscent of a cascading flow downward.

Figure 9 shows a closer view of the area in the yellow box in Figure 8. The region exhibited repeated vertical streaks and areas of material folded over adjacent areas. These features were consistent with smearing, or post-fracture damage. Isolated areas in Figure 9 were still undamaged though, as illustrated in Figure 10. This area exhibited dimpled rupture, consistent with fracture from overstress.

An area adjacent to the upper surface edge towards the right flange end is shown in Figure 11. This area was of note due to the flatter surface morphology and vertical-oriented parallel marks. A closer view of this area is shown in Figure 12. This region

² Evapo-Rust® — a commercially-available chelating rust stripper manufactured by Harris International Laboratories, headquartered in Springdale, AR.

generally exhibited localized smoothing and small, oblong divot features—these were consistent with the underlying material after the surface oxide product had been removed. Some small areas in larger recesses were relatively undamaged, as shown in Figure 12. These areas exhibited dimpled rupture, consistent with overstress fracture (see Figure 13).

Prior to cleaning the right side of the upper flange fracture surface (shown in Figure 14) showed a circular or thumbnail-like shape. This area was examined using a SEM, as shown in Figure 15. This region exhibited an undulating morphology, with a radial pattern, consistent with emanating from inward towards the upper face edge. Figure 16 shows a closer view of the center of this area, exhibiting pock-marked features. A closer view of these features revealed them to be dimpled rupture, consistent with overstress fracture. There were areas that exhibited a lamellar appearance, consistent with the underlying material microstructure exposed after removal of the oxide on the fracture surface.

All the features examined on the different areas of the connecting rod fracture surface were consistent with overstress fracture. There were no indications of pre-existing cracking features, such as striations or intergranular facets, which would suggest another distinct fracture mode.

Another section of the connecting rod was mounted, polished, and etched with 2% Nital to examine the microstructure.³ Figure 18 shows a typical area of the core microstructure, examined along the web/flange transition away from the rod surface. The microstructure exhibited tempered martensite and proeutectoid ferrite, consistent with a quench and tempered medium-low carbon steel. Figure 19 shows an area of the microstructure along the surface at the top of the flange face. This microstructure was comparable to that of the core, indicating a lack of decarburization or any underlying surface treatments to the part.

The composition of the rod was examined using energy dispersive x-ray spectroscopy (EDS) in the SEM. The composition was consistent with an alloy steel. In addition, lead and bromine were detected, consistent with the combustion byproducts of tetraethyllead additives in avgas.

The hardness was performed on the sectioned rod remnant per ASTM E18.⁴ The hardness averaged 28 HRC.⁵ These data were consistent with the composition and microstructure observed for the rod.

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³ 2% Nital – a mixture of 2% concentrated nitric acid (HNO₃) in ethanol (C₂H₅OH)

⁴ ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

⁵ HRC (Hardness, Rockwell C scale) – an indentation method of determining the hardness of harder metal alloys using a conical diamond indenter and 150 kg major load.



Figure 1 – View of the connecting rod remnant from (a) the side (web) and (b) a flange face.



Figure 2 – View of the fracture surface of the connecting rod fragment, as received.



Figure 3 – The fracture surface from Figure 2, after sectioning from the rod fragment.



Figure 4 – Closer view of the upper flange in Figure 3, after sectioning but before cleaning.



Figure 5 – The flange section shown in Figure 4, after cleaning.



Figure 6 – Planar view of the face of the flange in Figure 4, showing deformation near the fracture.



Figure 7 – Side view of the rod fragment fracture surface section, demonstrating the slanted fracture orientation on the web.

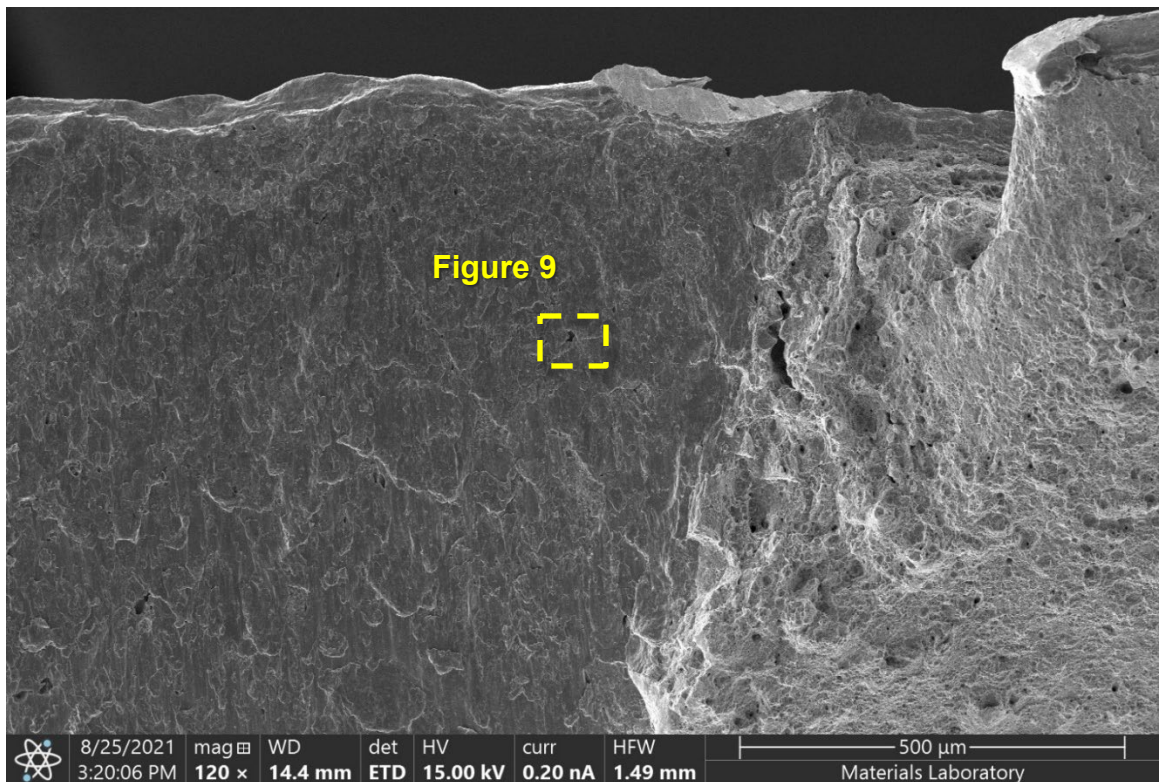


Figure 8 – Secondary electron (SE) micrograph of the central area of the flange fracture.

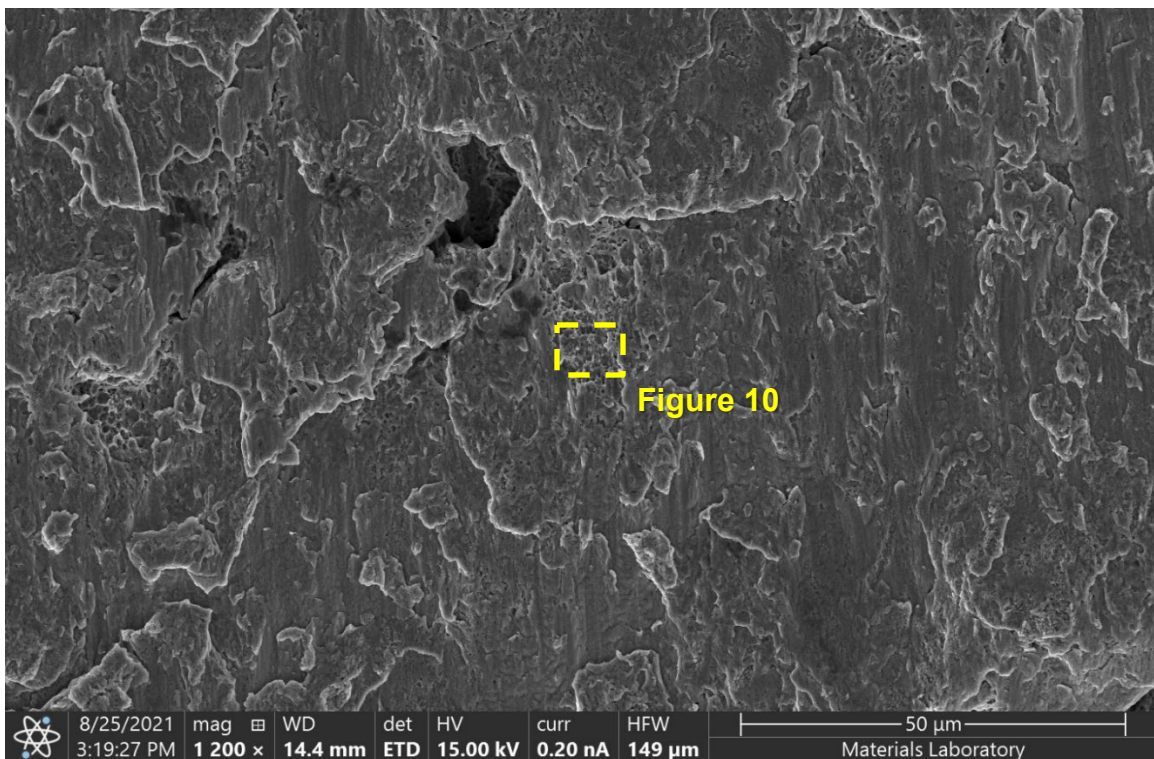


Figure 9 – SE micrograph of the boxed area in Figure 8, showing vertical smearing.

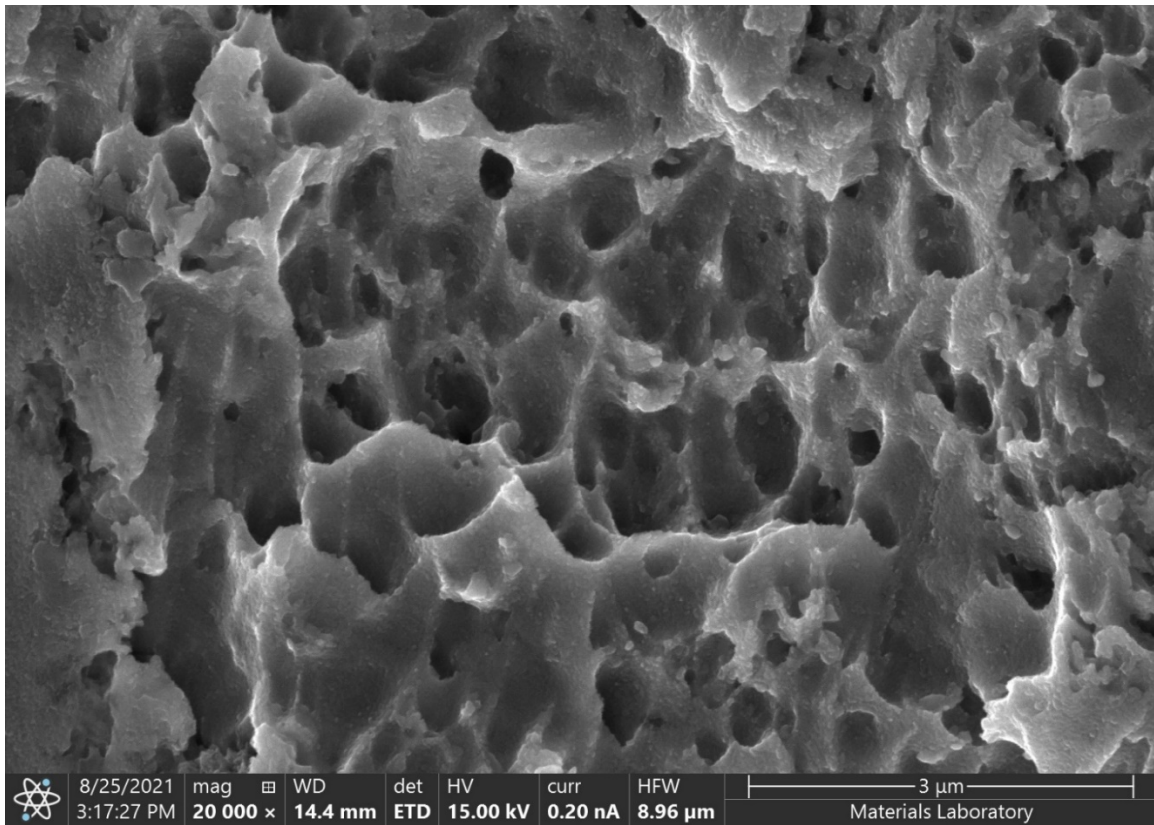


Figure 10 – SE micrograph of the boxed area in Figure 9, showing dimpled rupture.

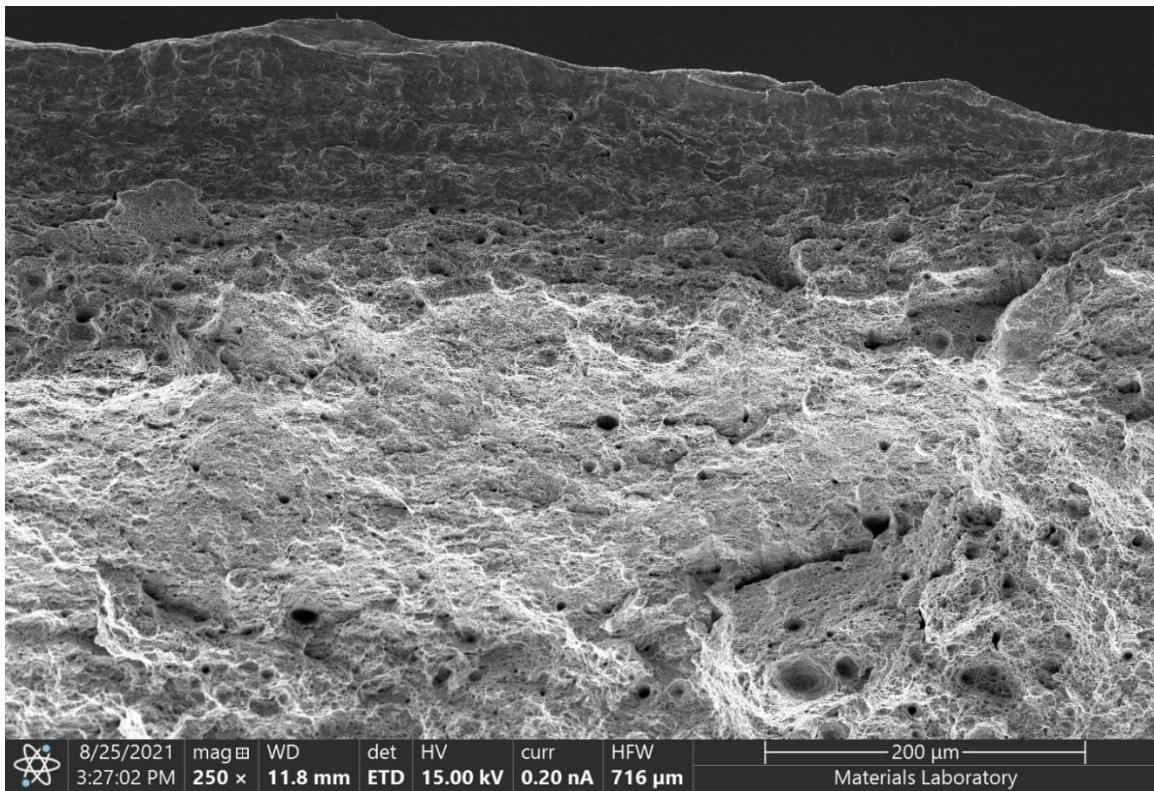


Figure 11 – SE micrograph of the edge of the fracture area shown in Figure 14.

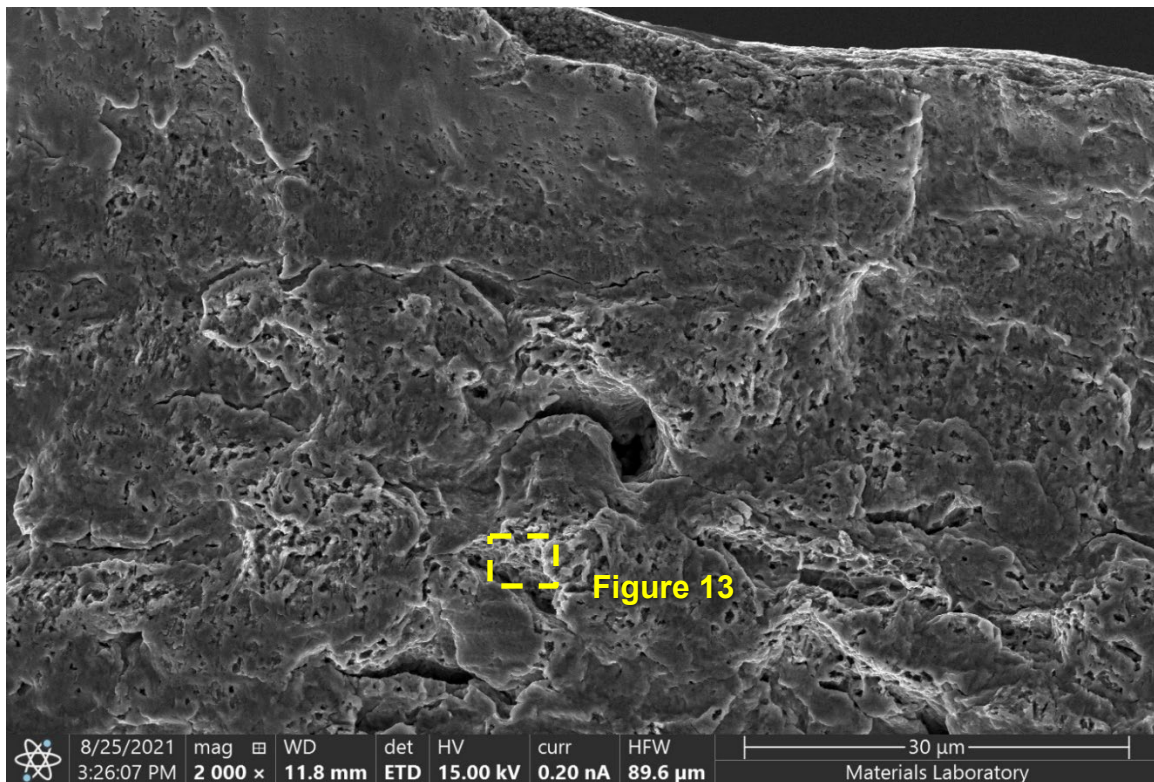


Figure 12 – SE micrograph of the smoother near-edge area in Figure 11.

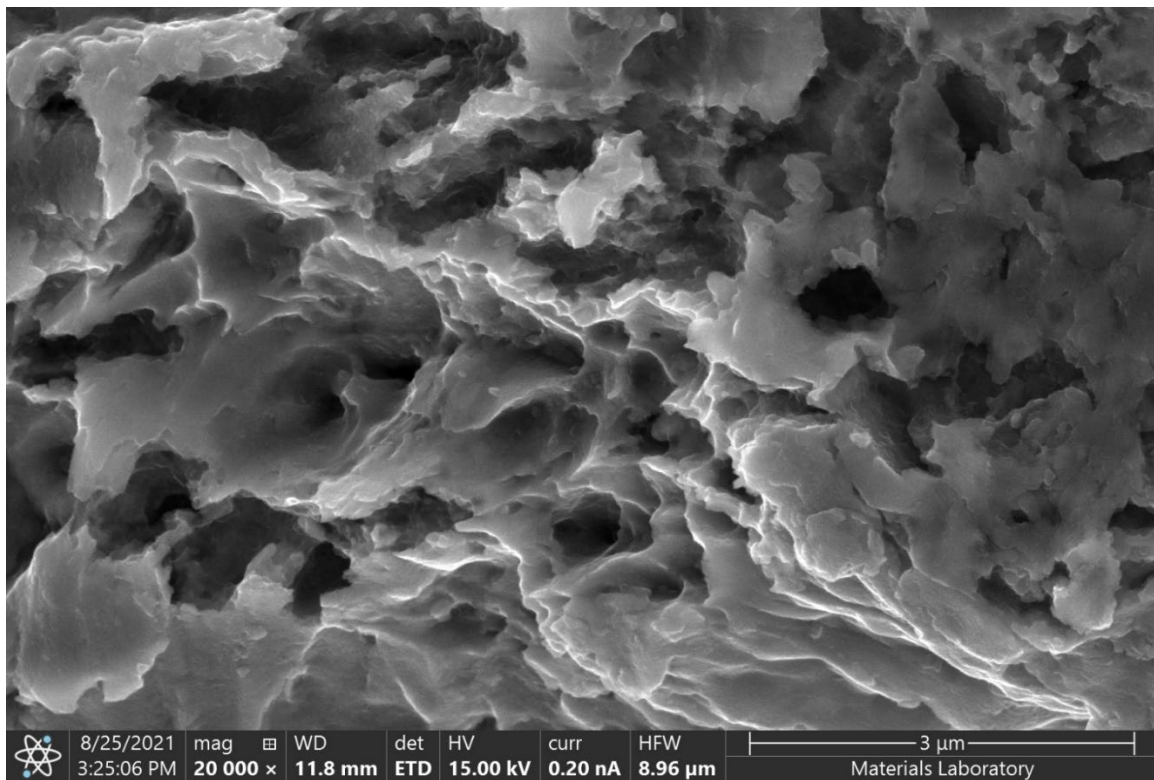


Figure 13 – SE micrograph of dimpled rupture in the boxed area in Figure 12.

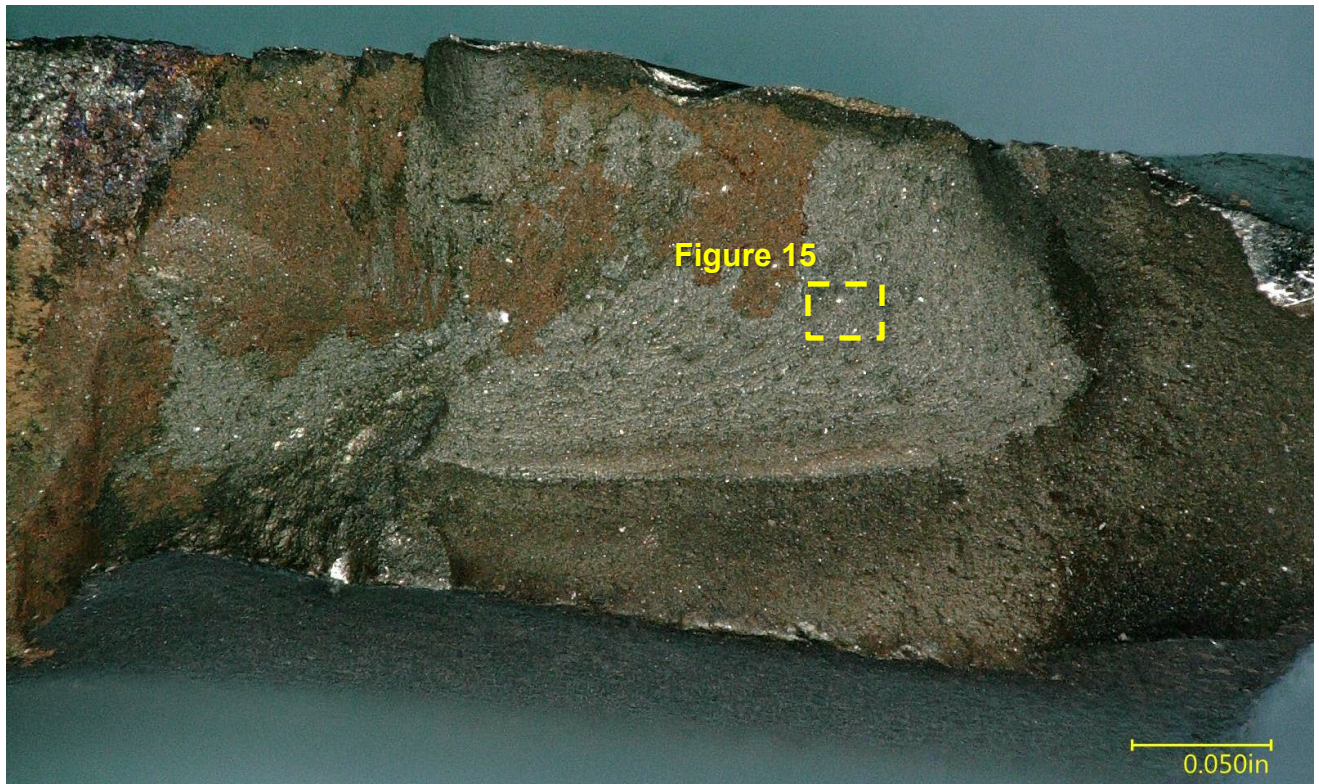


Figure 14 – View of the right side of the flange fracture surface in Figure 4, before cleaning.

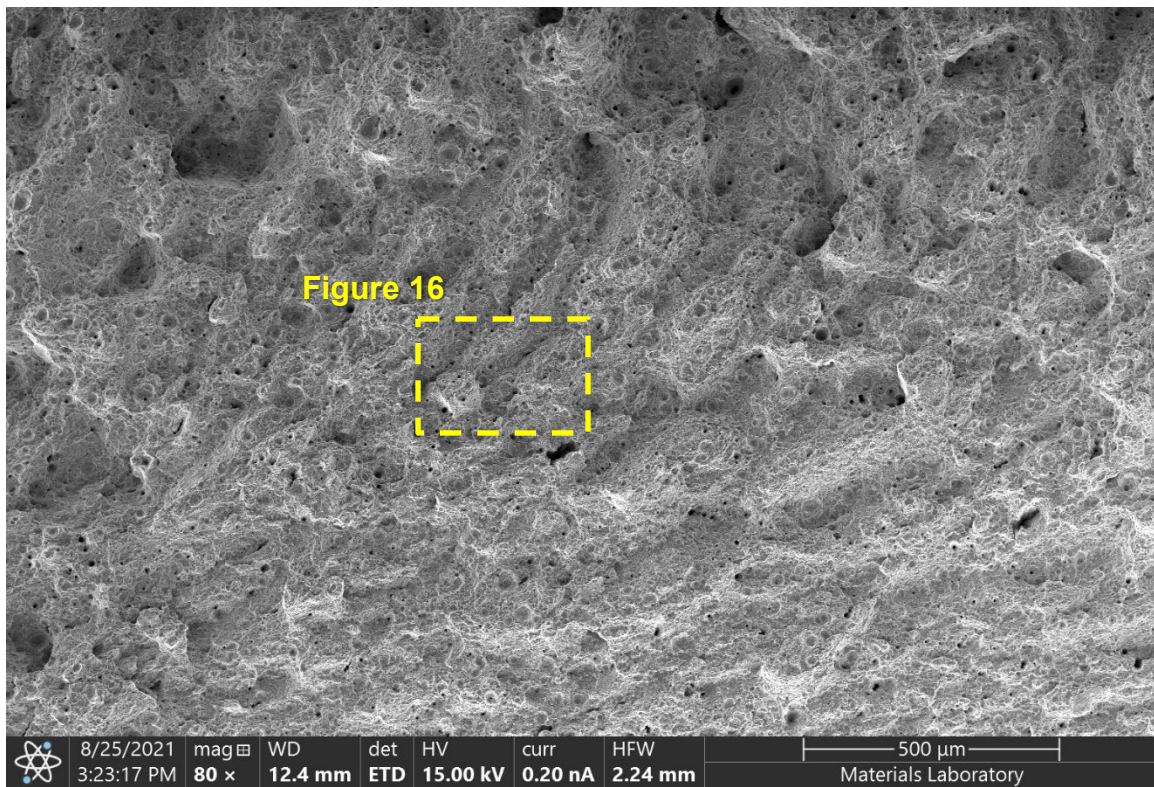


Figure 15 – SE micrograph of the middle of the area shown in Figure 14.

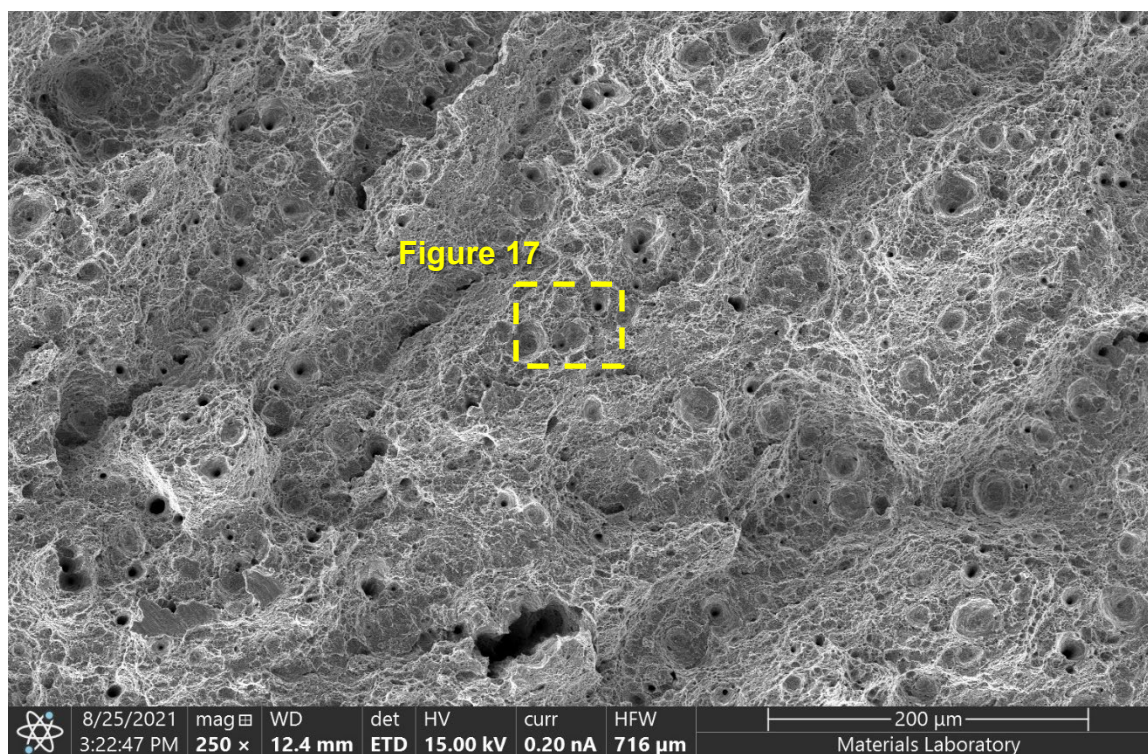


Figure 16 – SE micrograph of a closer view of the ridge features in Figure 15.

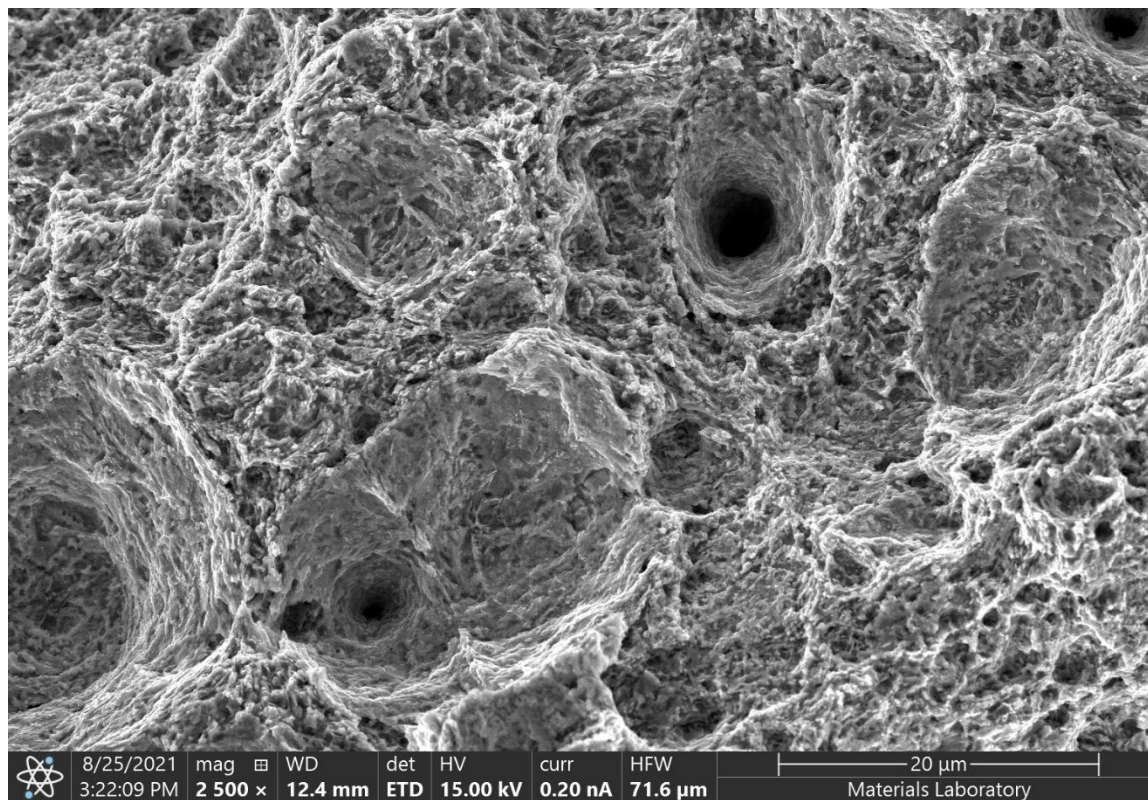


Figure 17 – SE micrograph of the boxed area in Figure 16, showing the remnants of dimpled rupture features after surface cleaning.



Figure 18 – Bright-field (BF) optical micrograph of a typical area of the rod microstructure from an area of the core, or away from the surface (~500X, etched 2% nital).



Figure 19 – BF optical micrograph of a typical area of the rod microstructure adjacent to the surface (~500X, etched 2% nital).