

NATIONAL TRANSPORTATION SAFETY BOARD

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



January 31, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 18-001

1. ACCIDENT INFORMATION

Place : Rockville, Idaho
Date : May 26, 2017
Vehicle : Bell 206B, N24FS
NTSB No. : WPR17LA113
Investigator : Joshua Cawthra, AS-WPR

2. COMPONENTS EXAMINED

Engine-to-transmission shaft and shaft flanges
Flexure coupling element remnants
RPM detector box

3. DETAILS OF THE EXAMINATION

On May 26, 2017, about 1044 mountain daylight time, a Bell 206B, sustained substantial damage during a forced landing near Rockville, Idaho. The commercial pilot, the sole occupant of the helicopter, was seriously injured. The pilot reported that as he performed a 180° turn about 40 to 50 feet above ground level, he heard a grinding noise followed by a loud bang and subsequent loss of power. The pilot stated that he initiated an autorotation landing to a nearby field. The helicopter was recovered to a secure location for further examination. Several components from this location were sent to the NTSB Materials Laboratory for examination.

Figure 1 shows the pieces from the helicopter accident, as received. In the figure are components of an engine-to-transmission driveshaft, manufactured by Kamatics.¹ The driveshaft components submitted include the main shaft body assembly, the aft transmission shaft flange, the forward engine shaft flange, and multiple fractured flexure elements from the flexure coupling(s). In addition, an electronic RPM detector box was submitted.

¹ Kamatics, a division of Kaman (headquartered in Bloomfield, CT), manufactures an PMA engine-to-transmission *KAflex* driveshaft, designed to reduce maintenance by reducing periodic lubrication.

The RPM detector box exhibited multiple, repeated deep gouge marks on the external housing surface. This damage was consistent with repeated contact with an adjacent part after it had fractured.

The shaft portion section of the transmission shaft flange, facing the flex-coupling, had fractured between 0.5 and 1 inches from the flange radius, as shown in Figure 2. The shaft exhibited circumferential wear and gouge marks, consistent with contact with an adjacent component, post-fracture. The fracture surface was obliterated by this post-fracture contact. The areas adjacent the fracture surface exhibited buckling and twisting consistent with rotational or torsional loading.

The bolts, as received, were intact and still connected to the flange. Of note was an affixed flexure element that had fractured in two locations, still attached to the flange. These fractures were located approximately 0.4 inches from the bolt hole. The fractures exhibited a general cup-like profile, with a general rough texture and dull luster. The areas adjacent the fractures on the flexure element had thinned or necked. These fracture features were consistent with overstress failures.

The shaft body of the engine-to-transmission drive shaft is shown in Figure 3. The outer surface of the shaft body was marked:

FAA-PMA
KAMATICS CORPORATION
P/N SKCP2348-101

FOR INSTALL[...]
[...]

The remainder of the markings were damaged from gouging and scraping, consistent with post-fracture contact damage with an adjacent component. The shaft body itself exhibited circumferential wear and gouge marks near the center flange on the bottom of the marking label. The forward side of the shaft body exhibited inward buckling, deformation, and obliteration consistent with repeated impact and smearing with an adjacent component. These marks were consistent with those present on the mating transmission flange.

Likewise, the aft portion of the shaft body exhibited inward buckling deformation, as well as interior and exterior rotational wear marks. These marks were consistent with those on the aft engine shaft flange. The aft shaft body flange had exhibited deformation forward.

The attachment bolts on all the shaft body flanges were still fastened. The flexure element remnants had fractured away from the bolt holes. These fracture surfaces exhibited features that were similar to those of the flexure element remnants on the transmission shaft flange.

In addition, on the aft side of the shaft body, the element remnant fractures mated with those on the engine shaft flange (shown in Figure 4). These four fracture surfaces were located away from the bolt holes, and exhibited similar features. The fracture surfaces were rough textured, with either a cup or cone shape, or a 45° angle orientation. The areas adjacent to the fracture surfaces exhibited local deformation and necking, as well as small parallel cracks. These features were consistent with overstress fracture.

Of note, as shown in Figure 1, was a flexure element that had fractured along a bolt hole. This element is highlighted in Figure 5 and Figure 6. The fractures were flat, with no indications of localized material deformation or necking. The pair of fracture surfaces about the bolt hole is shown edge on in Figure 7.

An angled view of the element at the fractured bolt hole is shown in Figure 8. The flat surface exhibited a smooth, circular-shaped depression. The inner surface of the bolt hole also exhibited wear on a portion of the wall (identified in Figure 8). This wear was significant enough to create material loss on the bolt hole wall (see Figure 9). The flexure element thickness was measured with calipers. The thickness of the unworn areas of the flexure element were 0.150 inches. The thickness of the element in the circular-shaped worn depression was 0.136 inches.

Several of the other flexure elements that were still fastened, as received, were disassembled to inspect for similar wear. The type wear leading to material loss was not observed about the other disassembled element bolt holes, as exemplified in Figure 9. The circular-shaped depression of the fractured flexure element was compared with a washer from a disassembled bolt. As shown in comparing Figure 10a and Figure 10b, the size and shape of the depression was consistent with the adjacent washers that had been installed. The peripheral wear marks in this depression shown in Figure 8 were consistent with rotational contact with an adjacent washer.

For the purposes of this report the flexure element fractures about the bolt hole were labeled “left” and “right” fracture, based on their orientation in Figure 11. The left fracture is shown in Figure 12 and is shown as examined using a scanning electron microscope (SEM) in Figure 13. The left fracture surface exhibited crack arrest marks consistent with progressive cracking from the lower portion of Figure 13 upward. A closer examination of this fracture surface found fatigue striations, consistent with fatigue fracture, as illustrated in Figure 14.

Figure 15 shows the general crack initiation site of the left fracture. The exact initiation site(s) could not be determined, due to post-fracture damage. However, as shown in Figure 16, the fatigue crack initiation site corresponded to the location of the washer-shaped depression. Plastically deformed material was also present at the fatigue crack initiation site on the left fracture.

The right fracture is shown in Figure 17, and as observed in a SEM in Figure 18. While the right fracture surface was more damaged than the left, prominent crack arrest marks were present on this fracture surface. As with the left fracture surface, fatigue

striations were prevalent over much of the right fracture surface (see Figure 19). Outside the fatigue crack regions, the rest of the undamaged right fracture surface exhibited dimple rupture, consistent with subsequent overstress fracture, as illustrated in Figure 20.

The fatigue crack initiation site of the right fracture was partially damaged. However, there were no indications that the initiation site contained any material discrepancies such as corrosion pits or oxide inclusions (Figure 21). The location of the right fatigue crack initiation site was at an area of local deformation, consistent with the edge of the washer-shaped depression.

One of the walls of the flexure element that fractured at the bolt hole was sectioned, mounted and polished. The location of this cross-section is annotated in Figure 9. The polished cross-section is illustrated in Figure 22. As shown in the cross section, the circular-shaped depression was evident in the upper right side. The transition of the depression wear is highlighted in Figure 23. Of note in the depression was the lack of an outer coating, consistent with prolonged wear and material loss. When inspected using energy dispersive x-ray spectroscopy (EDS), the coating was found to be consistent with cadmium plating. Inspection of the inside bolt hole wall revealed several small cracks, up to 0.005 inches deep. One such crack is illustrated in Figure 24.

The chemical composition of the fractured element was inspected using EDS and x-ray fluorescence (XRF). The chemical composition was found to be consistent with a maraging steel.² The microstructure of the flexure element is shown in Figure 25. The microstructure exhibited martensite and second-phase intermetallic precipitates, consistent with typical constituents in microstructures for this chemical composition. The hardness was inspected per ASTM E18.³ The hardness averaged 51 HRC, which was consistent with values typical of maraging steels.

Erik M Mueller
Materials Research Engineer

² Maraging steels are a specialty class of steel alloys that are hardened by metallurgical reactions that do not involve carbon. These class of steels are strengthened by the precipitation of intermetallic compounds, and typically exhibit compositions with high nickel, cobalt, and molybdenum contents, with very low carbon content.

³ ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

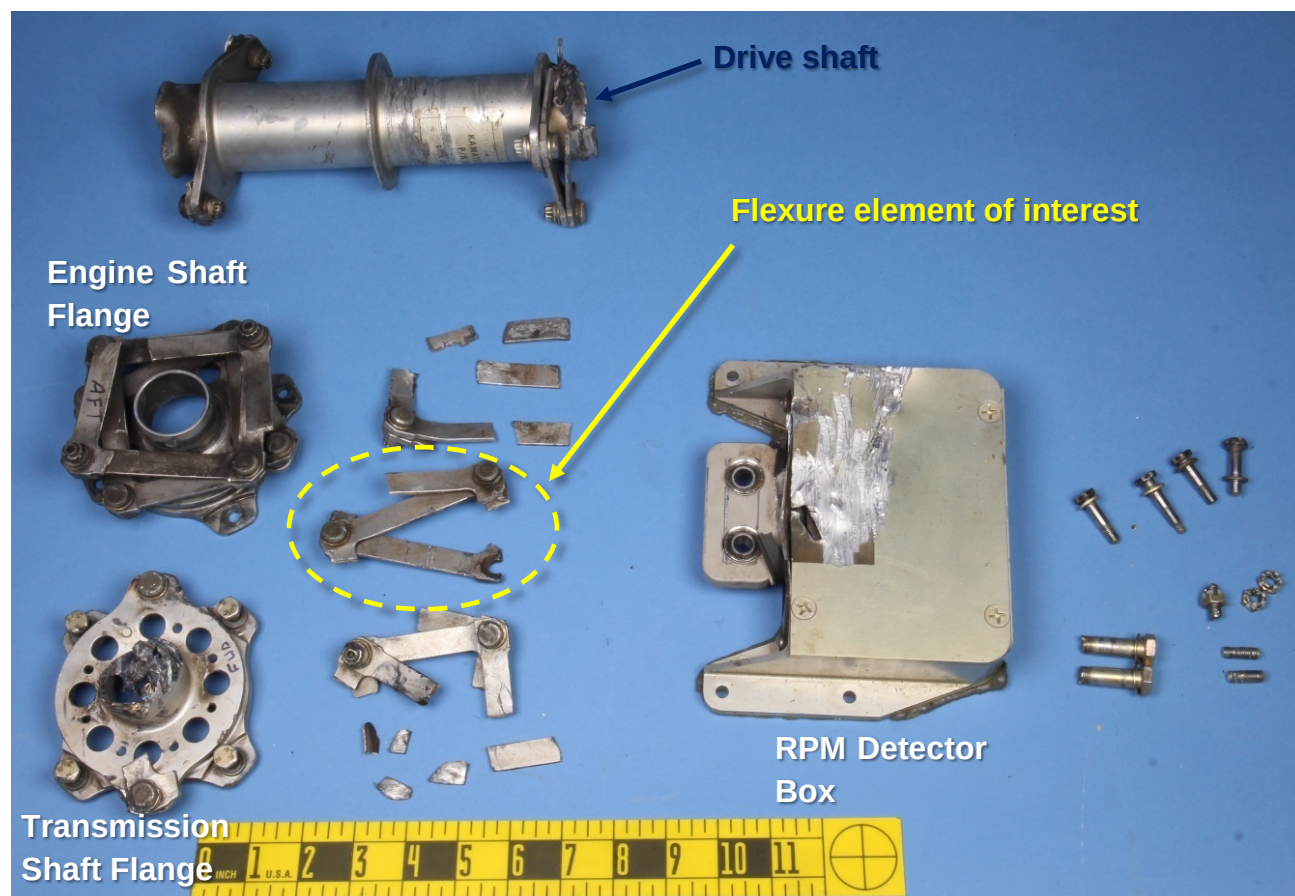


Figure 1 – The pieces of the KAflex main rotor driveshaft, as received.



Figure 2 – Closer view of the forward transmission shaft flange, showing shaft fracture and gouging, as well as a flexure element fracture (arrows).



Figure 3 – Closer view of the main shaft, showing the markings and the circumferential gouge marks.



Figure 4 – The remnant of the aft engine shaft flange coupling flexure elements.



Figure 5 – Some of the fractured flexure elements, showing two flat fractures around a bolt hole of interest.



Figure 6 – The fractured flexure elements from Figure 5, viewed from the reverse side.

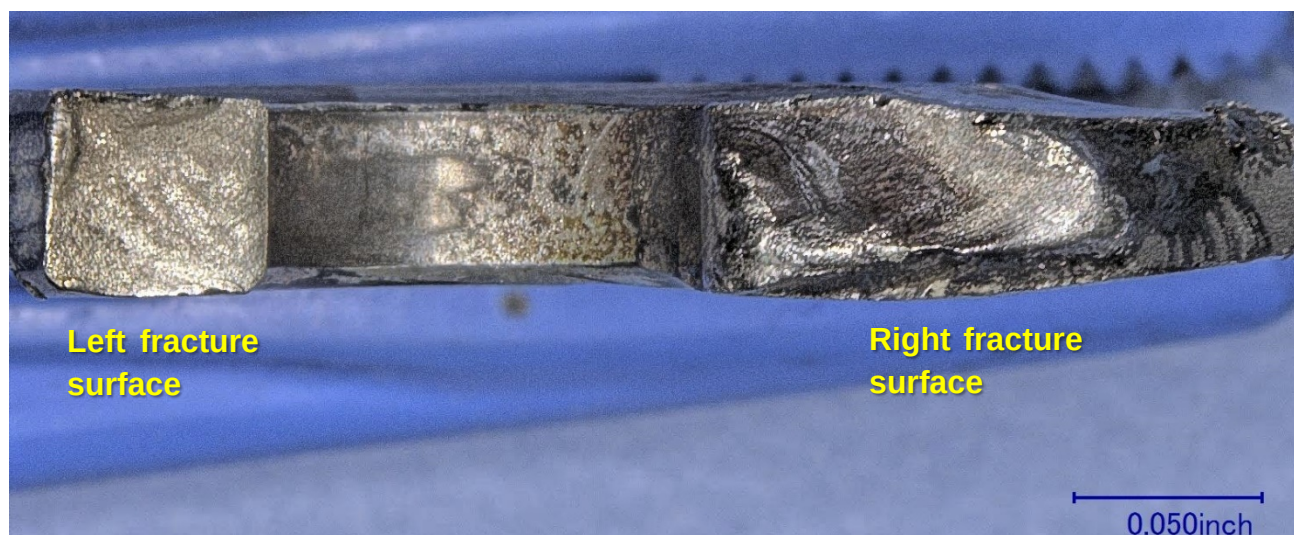


Figure 7 – The flat fracture surfaces of note from the flexure elements, after sectioning and cleaning.

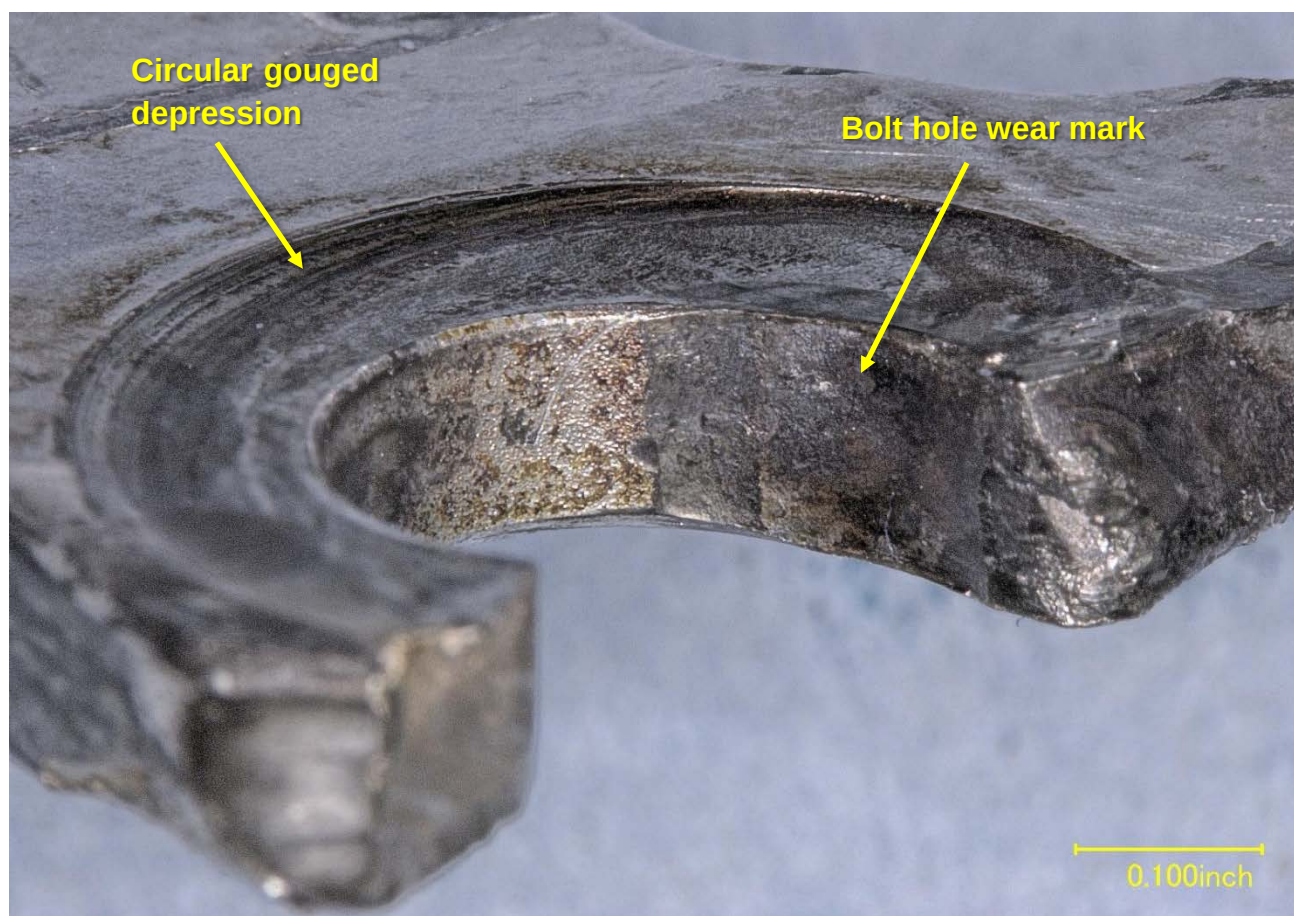


Figure 8 – The fracture surfaces of the flexure element in Figure 7, tilted at a 45° angle to show the gouged washer depression.



Figure 9 – The circular worn surface of the fractured flexure element (left), compared to an adjacent disassembled flexure element bolt hole, showing wear but no depression (right).

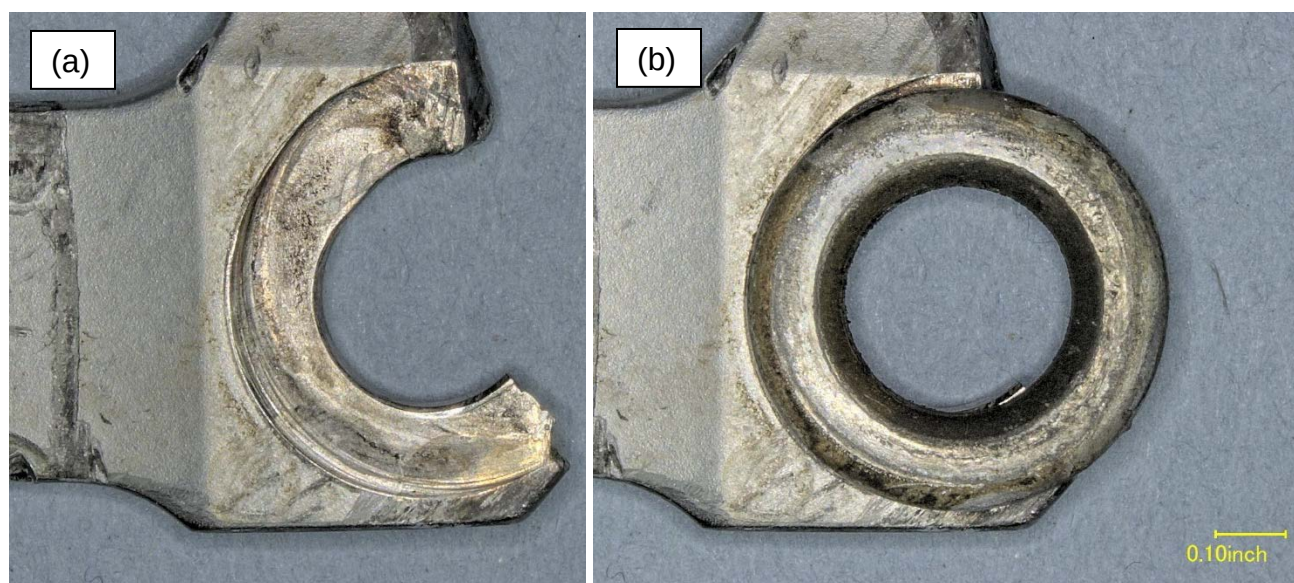


Figure 10 – The circular worn surface of the fractured flexure element (a) as fractured after cleaning and (b) with a washer placed in the circular depression.



Figure 11 – An angle view of the flexure element fracture surfaces, viewed opposite Figure 8.

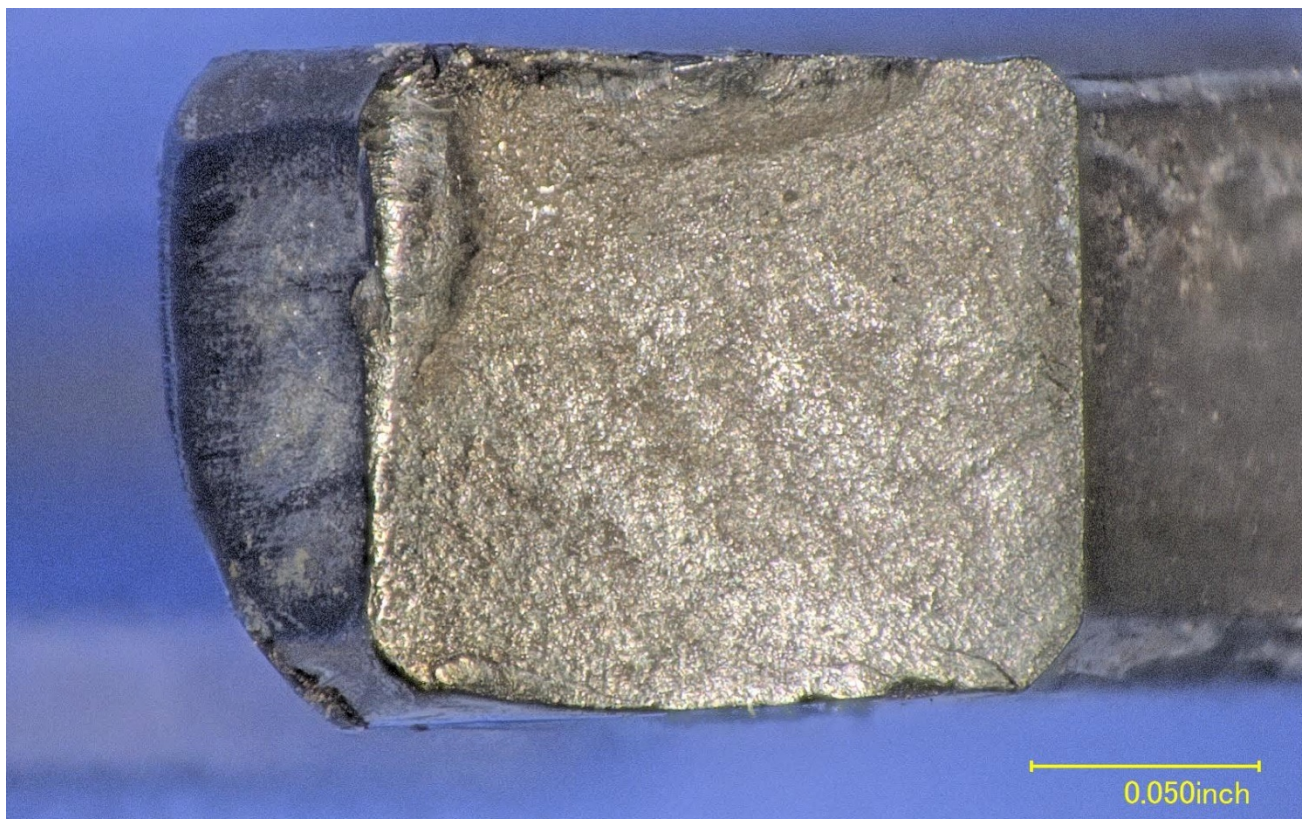


Figure 12 – A closer view of the left fracture surface in Figure 11.

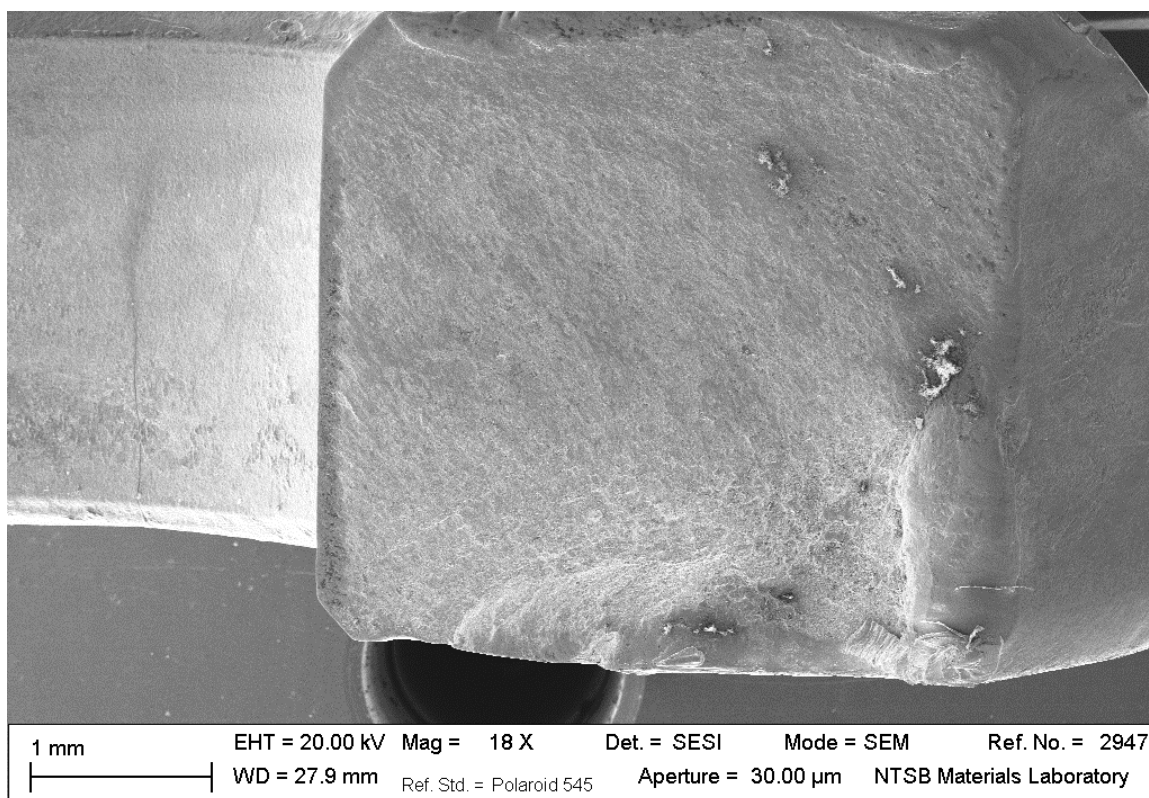


Figure 13 – Secondary electron (SE) micrograph of the left fracture surface.

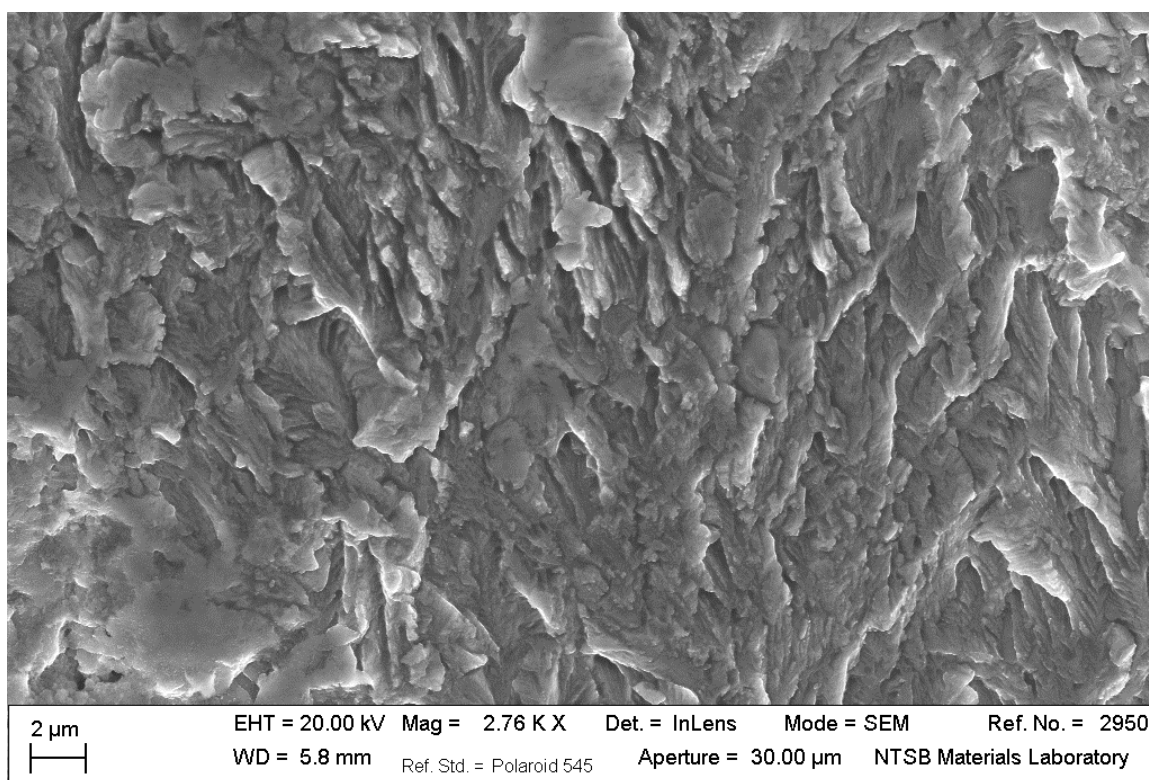


Figure 14 – SE micrograph of a typical area of the fracture surface in Figure 13, showing fatigue striations.

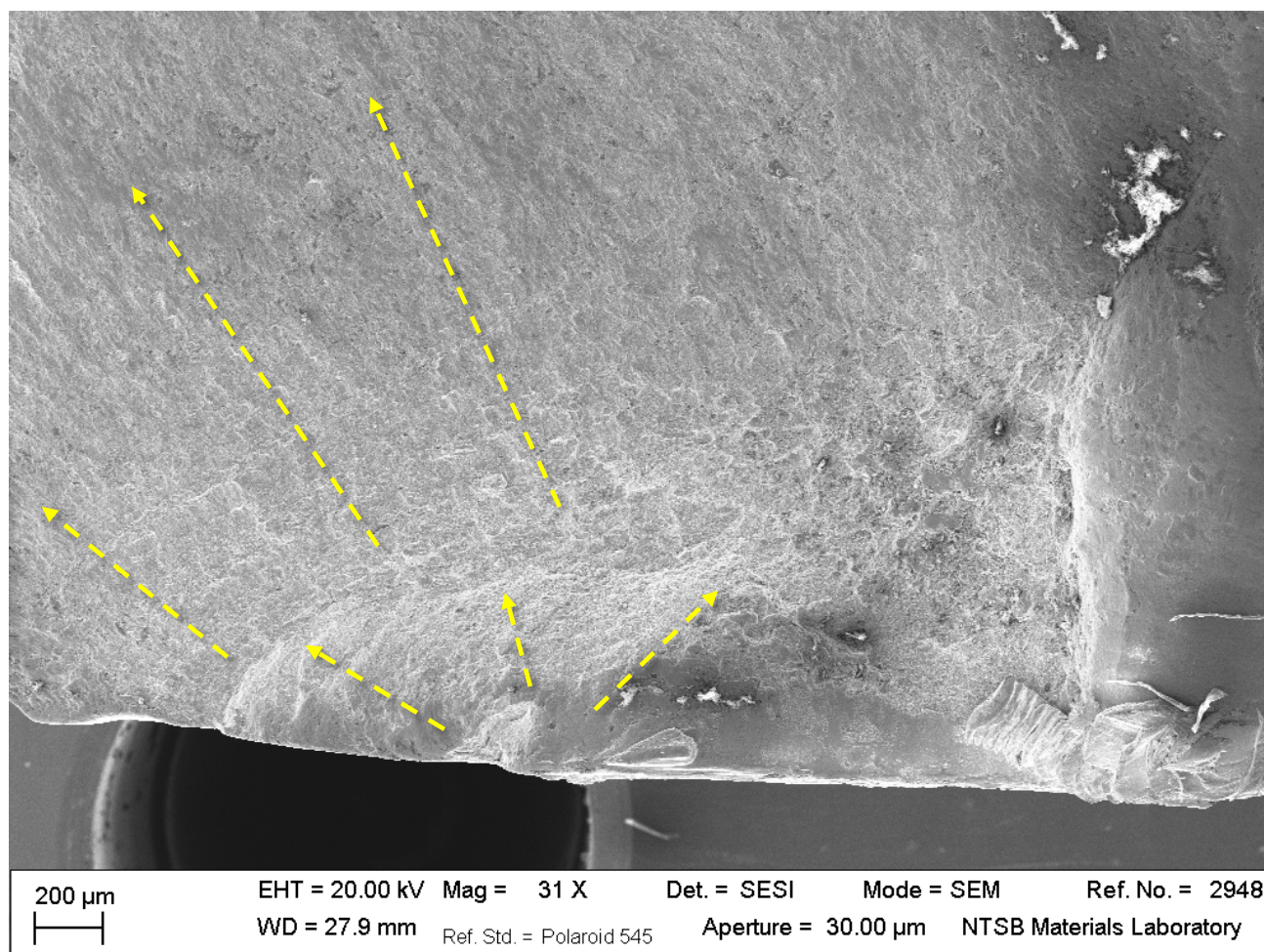


Figure 15 – SE micrograph of the crack initiation site of the left element fracture surface. The arrows denote the general crack growth direction.

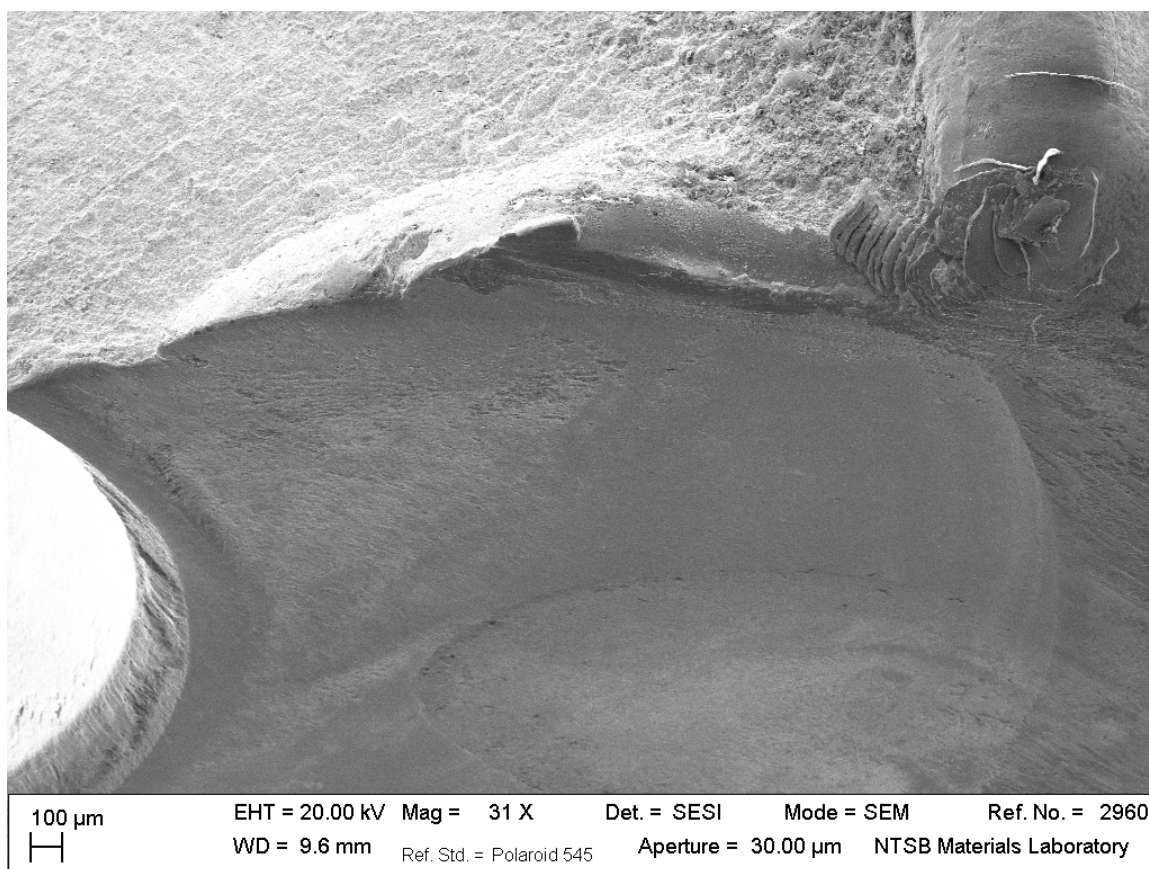


Figure 16 – SE micrograph of an angled view of the element fracture surface.



Figure 17 – The right fracture surface of the fractured flexure element in Figure 11.

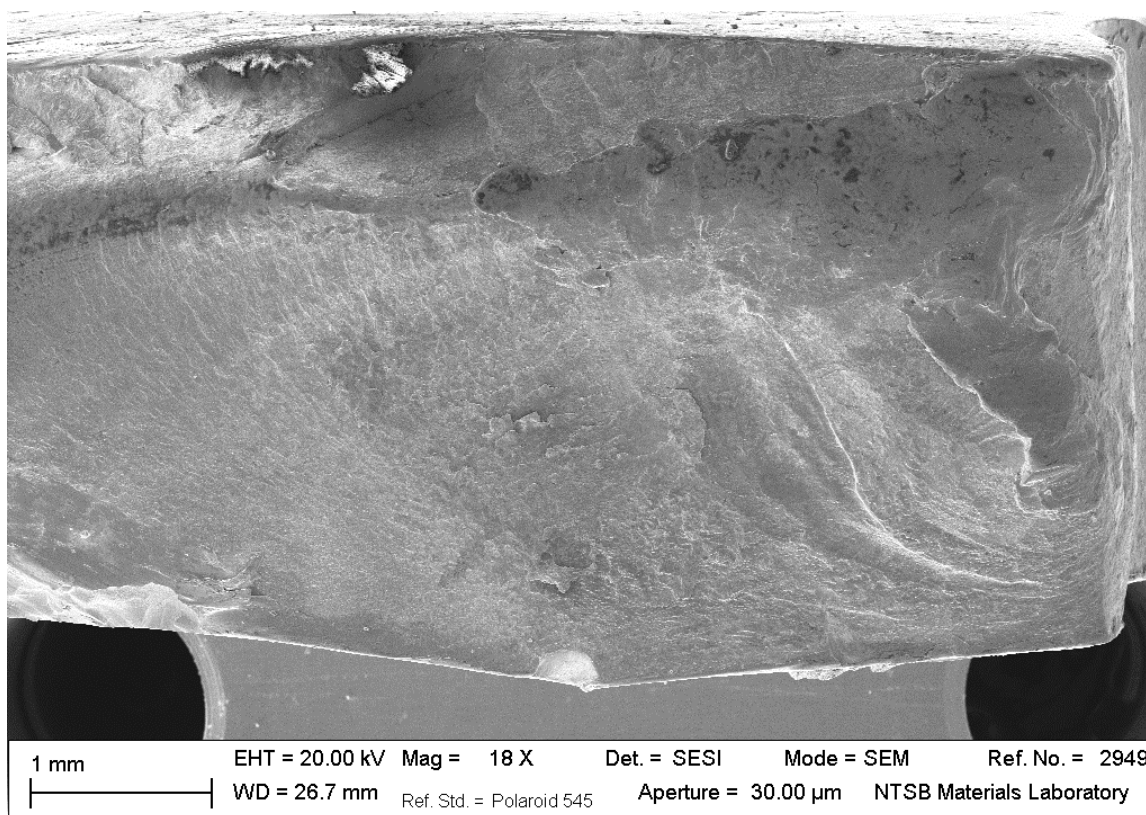


Figure 18 – SE micrograph of the element fracture surface in Figure 17.

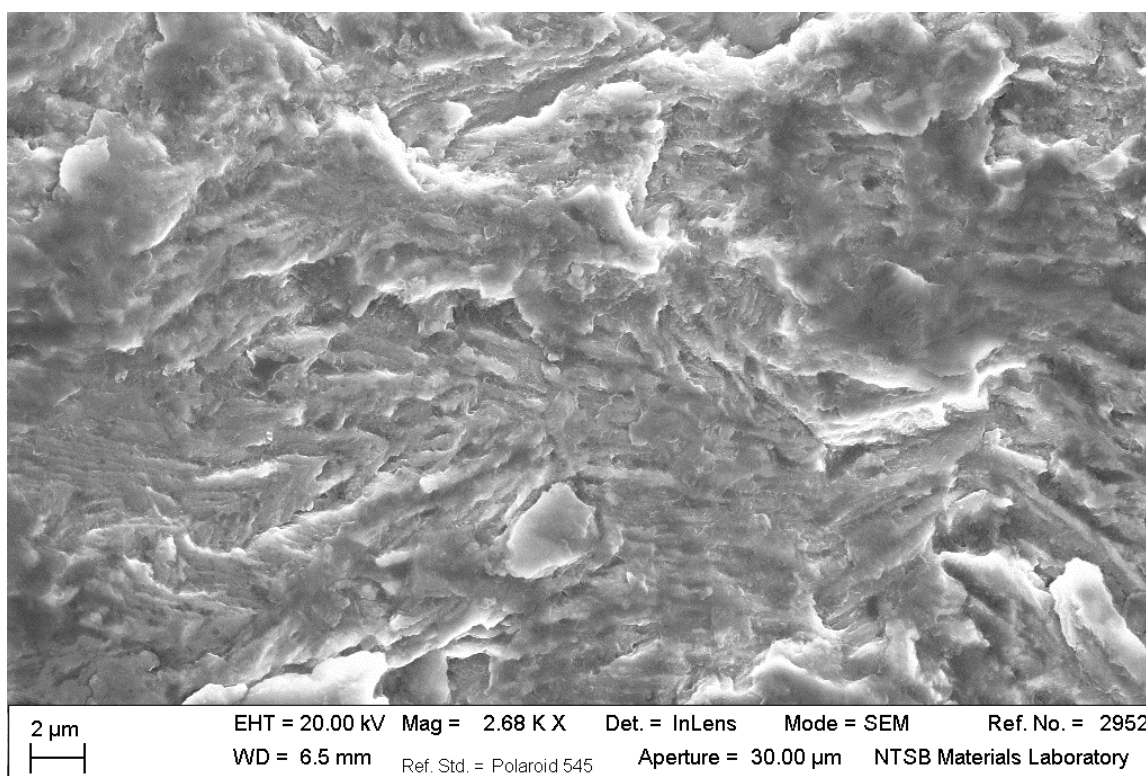


Figure 19 – SE micrograph of fatigue striations on the right fracture surface.

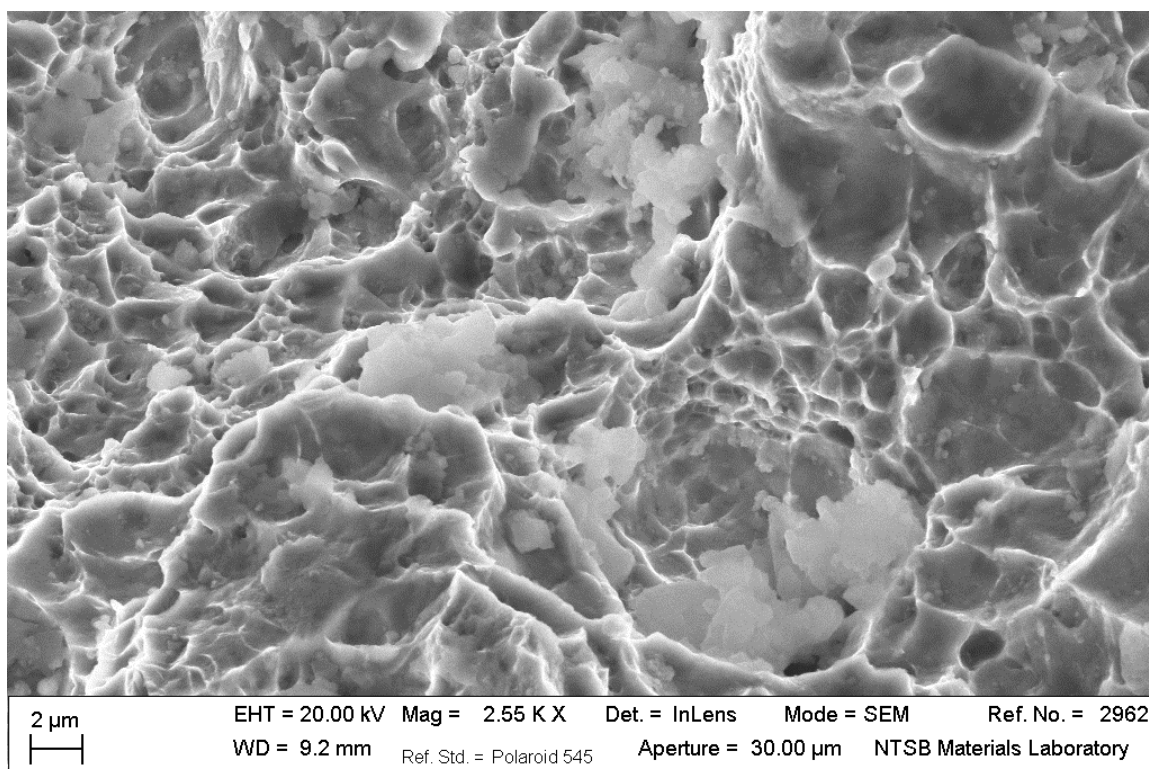


Figure 20 – SE micrograph showing dimple rupture outside of the fatigue regions on the right element fracture surface.

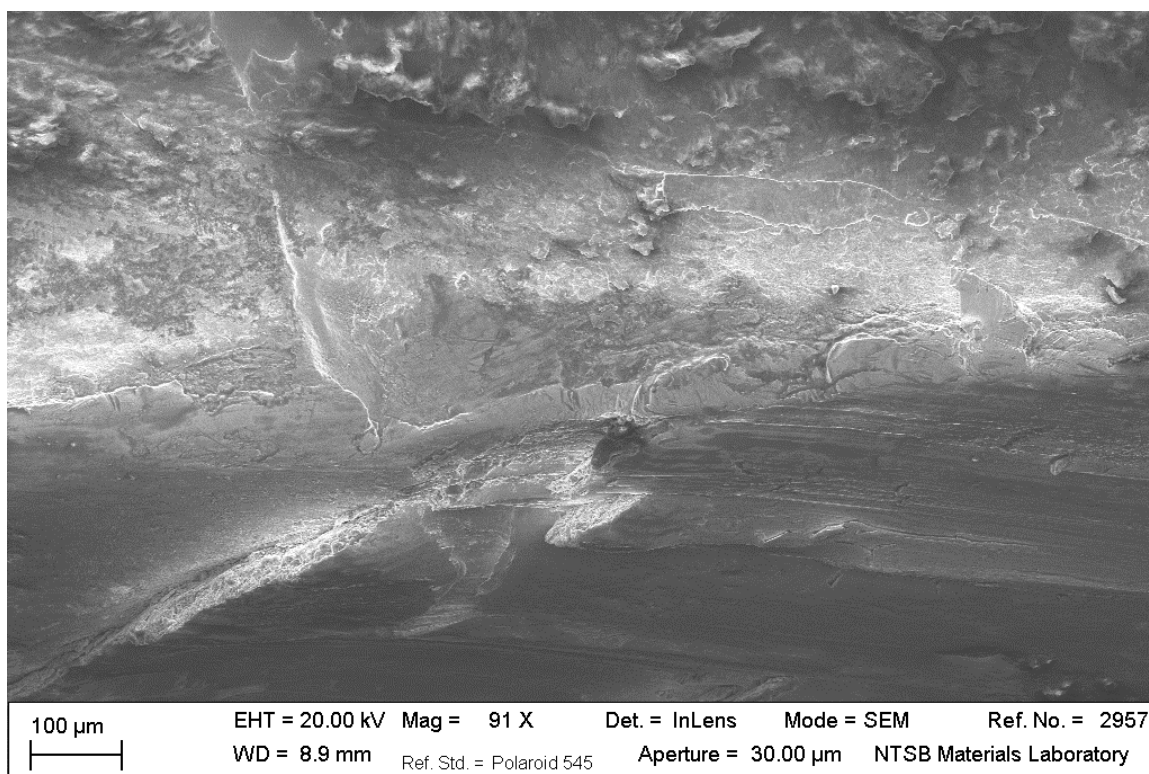


Figure 21 – SE micrograph showing the fatigue crack initiation site of the right element fracture surface.

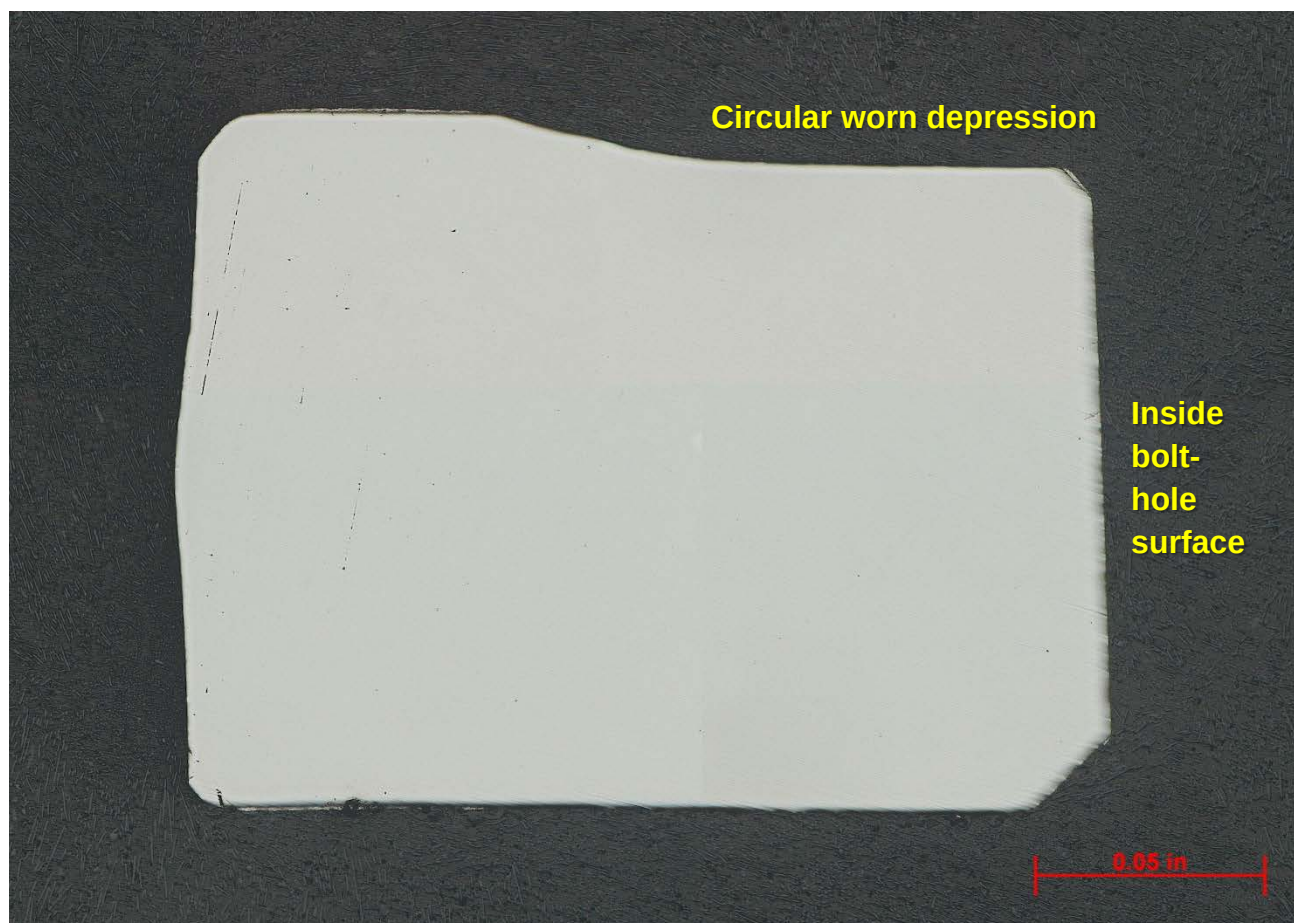


Figure 22 – Bright field (BF) optical micrograph of a cross-section of the side of the fractured flexure element bolt hole (location shown in Figure 9) (as-polished, ~25X).

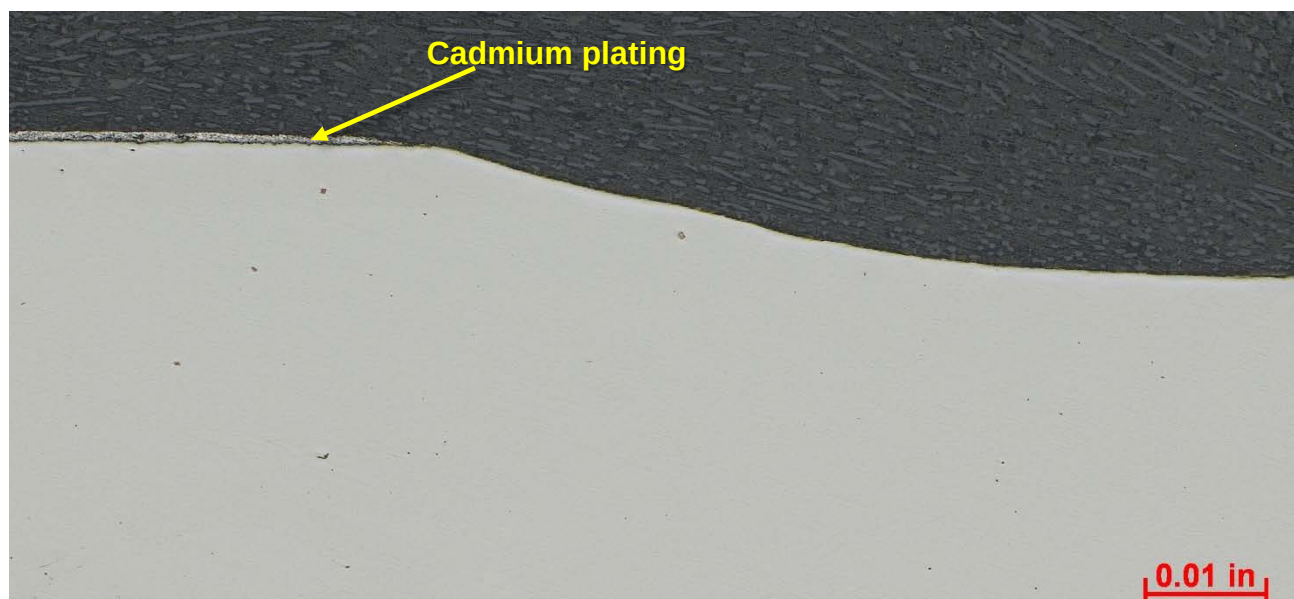


Figure 23 – BF optical micrograph showing the worn surface of the circular-shaped worn depression (right side) from the upper surface of Figure 22 (as-polished, ~50X).



Figure 24 – BF optical micrograph showing the inside bolt hole surface of the flexure element, showing a small crack (as-polished, ~200X).

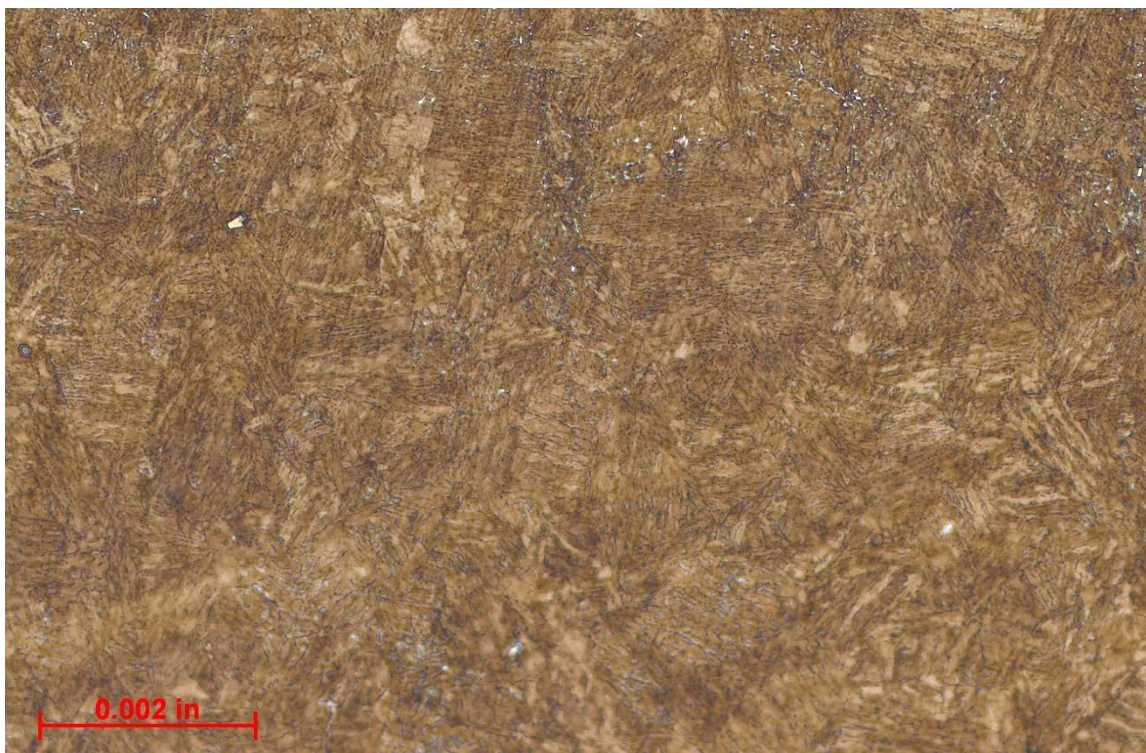


Figure 25 – BF optical micrograph of a typical area of the flexure microstructure, exhibiting martensite laths and intermetallic precipitate phases (~500X, etched 2% Nital).