

NATIONAL TRANSPORTATION SAFETY BOARD

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



February 27, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 18-012

1. ACCIDENT INFORMATION

Place : Homerville, Georgia
Date : May 9, 2017
Vehicle : Cessna 150M, N714DW
NTSB No. : ERA17LA176
Investigator : Todd Gunther, AS-ERA

2. COMPONENTS EXAMINED

Fractured pieces of #4 cylinder
Piston remnant
Pieces from connecting rod assembly

3. DETAILS OF THE EXAMINATION

On May 9, 2017, about 1525 eastern daylight time, a Cessna 150M, N714DW, was substantially damaged during a forced landing in Homerville, Georgia. The private pilot was not injured. According to the pilot, he heard an unusual sound come from the engine, noticing decrease in engine RPM. The pilot reported that smoke emanating from the engine entered the cockpit, and a small piece of debris struck the windshield. According to FAA and maintenance records, the airplane was manufactured in 1976. Its most recent annual inspection was completed on May 3, 2017. At the time of the inspection, the airplane had accrued 7309.6 total hours of operation, and the engine had accrued about 2217.2 total hours since major overhaul. The engine was a Continental O-200-A48 (S/N 205663-70A).¹

Figure 1 shows the pieces of the connecting rod, as received. The markings on the connecting rod stated, "5 6 0186 ATLAS 12". The connecting rod, cap, and bolts were all received intact, with no fractures. However, as shown in Figure 2, the rod body had been deflected along the web near the piston pin bore. The sides of the rod exhibited scraping or gouging damage (shown in the reflective areas of Figure 2).

The pin bore of the connecting rod had been deformed, consistent with elongation along the length of the rod. This is highlighted in Figure 1 and shown closer in Figure 3. As shown in Figure 3, this deformation was consistent with deformation toward the crankshaft (to the right in Figure 3). Minor rubbing marks were present of the side of the

¹ The O-200-A is a four-cylinder air-cooled horizontally opposed piston aircraft manufactured by Teledyne Continental Motors (TCM) in Mobile, AL.

pin bore walls of the connecting rod (the web deflection in Figure 2 is towards the reader in Figures 1 and 3). The bushing inside the pin hole bore was relatively undamaged.

The crankshaft bearing surfaces are shown in Figures 4a and 4b. These surfaces were intact, exhibiting minimal wear marks. This wear was not severe enough to leave any indications consistent with deformation, gouging, or spalling.

The piston is shown in Figure 5, as received. Much of the piston exhibited severe deformation and material loss. Figure 5b shows material consistent with caked on dirt or soil in the oil and guide ring notches. The fracture surfaces on the underside of the piston are shown in Figure 5a. These surfaces were heavily damaged due to post-fracture impact and corrosion damage. The still-present fracture features, such as faint river and chevron marks, were consistent with those of overstress fractures of reciprocating engine pistons. The pattern of features on these fracture surfaces was consistent with the fracture originating about the pin hole bore of the piston.

The cylinder assembly is shown in Figure 6, as received. The cylinder had fractured about the compression wall at the 10th cooling fin valley, when counted from the larger main body cooling fins of the cylinder head. This location was approximately 1.69 inches from the outboard, larger cooling fins (see Figure 6).

Figure 7 illustrates the halves of the cylinder positioned with the fracture surfaces facing the reader. The fracture was relatively flat and oriented normal to the direction of the piston actuation. The two cooling fins closest to the fracture exhibited bending and distortion. Several of the fin flange surfaces exhibited small circular features consistent with pitting.

The mating fracture surfaces are illustrated in Figure 7a and 7b. For the purposes of this report, the mating fractures are described as located on the head side and the piston, or open, side of the cylinder. Both fracture halves were relatively flat and exhibited a reflective luster. Much of the fracture surface had been damaged or entirely obliterated by post-fracture smearing or contact. Figure 8 shows a typical area of the fracture surface with little smearing damage. This damage was consistent with the visually apparent shiny, reflective luster of most of the fracture surfaces.

Closer examination of the head side fracture surface revealed that a portion exhibited crack arrest marks, consistent with progressive cracking that was later determined to be consistent with fatigue cracking (see Figure 8). The crack arrest features were present along approximately 30% of the fracture surface circumference (or approximately 110° of the circumference, which was approximately 3.8 inches long).

The crack arrest marks on both sides of the mating fracture surfaces propagated around the cylinder cross section from a singular point, highlighted in Figure 9 and Figure 10. As shown in Figure 6, the crack initiation site was located on the exterior surface of the cylinder fin valley. An initial thumbnail crack was present adjacent to the crack

initiation site, with radial marks and crack arrest marks propagating outward (see Figure 11).

The cylinder fracture surfaces were examined using a scanning electron microscope (SEM). Figure 12 illustrates a typical area of undamaged fracture surface near the end of the progressive cracking area, showing crack arrest marks and radial lines, consistent with the crack propagation direction. Inside this region, fatigue striations were present, consistent with fatigue crack propagation (see Figure 13). Outside the fatigue crack, dimple rupture, consistent with subsequent overstress fracture, was observed (see Figure 14).

The crack initiation site on the head side of the fracture surface is illustrated in Figures 15 and 16. The crack initiation site was relatively undamaged, exhibiting fatigue striations towards the fin root valley. As shown in Figure 16, the fracture surface at the crack initiation site exhibited a faceted morphology, with pit-like depressions on the fin valley surface. These features were consistent with local corrosion and pitting.

Multiple corrosion pits were present at the fatigue crack initiation site. The largest one is illustrated in Figure 17. The pit exhibited small facets consistent with local intergranular attack. The pit also exhibited local material loss, consistent with typical pitting corrosion. This and other pits contained non-conductive (non-metallic) compounds.

These compounds were inspected using energy dispersive x-ray spectroscopy (EDS). This examination the compounds to be consistent with an iron oxide, containing detectable levels of sodium, magnesium, phosphorus, potassium, sulfur, and calcium. These elements were not present in the bulk of the materials. Inspected using EDS, the chemical composition was found to be consistent with an alloy steel.

A portion of the cylinder and fins near the fracture surface was sectioned, mounted, and polished for metallographic examination. Of note were features present along the adjacent cooling fin valleys (see Figure 18). As shown in the figure, corrosion pits were present on the surface, with non-metallic compounds contained within. These corrosion pits were found on much of the surfaces examined in the cross-section (see Figure 19). The composition of these compounds, as examined using EDS, was consistent with that of the iron oxide compounds observed on the corrosion pits at the fatigue crack initiation site on the fracture surface.

On much of the examined cross-section cylinder surfaces, surface corrosion up to 0.076 inches thick was observed (see Figures 20 through 22). This surface corrosion, more readily observable using SEM examination, was present at all the examined fin valleys, as exemplified in Figures 21 and 22. The chemical composition of these compounds was consistent with that of the corrosion pit compounds. As shown in Figure 22, this surface corrosion compound was cracked and discontinuous. The underlying interface with the base metal was tortuous in morphology, consistent with widespread pitting corrosion.

Examination of the cylinder microstructure found it to be consistent with tempered martensite and occasional manganese sulfide particles, typical for this material see Figure 23.

Erik M Mueller
Materials Research Engineer



Figure 1 – The pieces of the connecting rod, as received. The elongated pin side is highlighted on the left.



Figure 2 – The connecting rod pieces in Figure 1, shown from the side to demonstrate the deflection in the web.



Figure 3 – A closer view of the elongated pin bore from Figure 1.

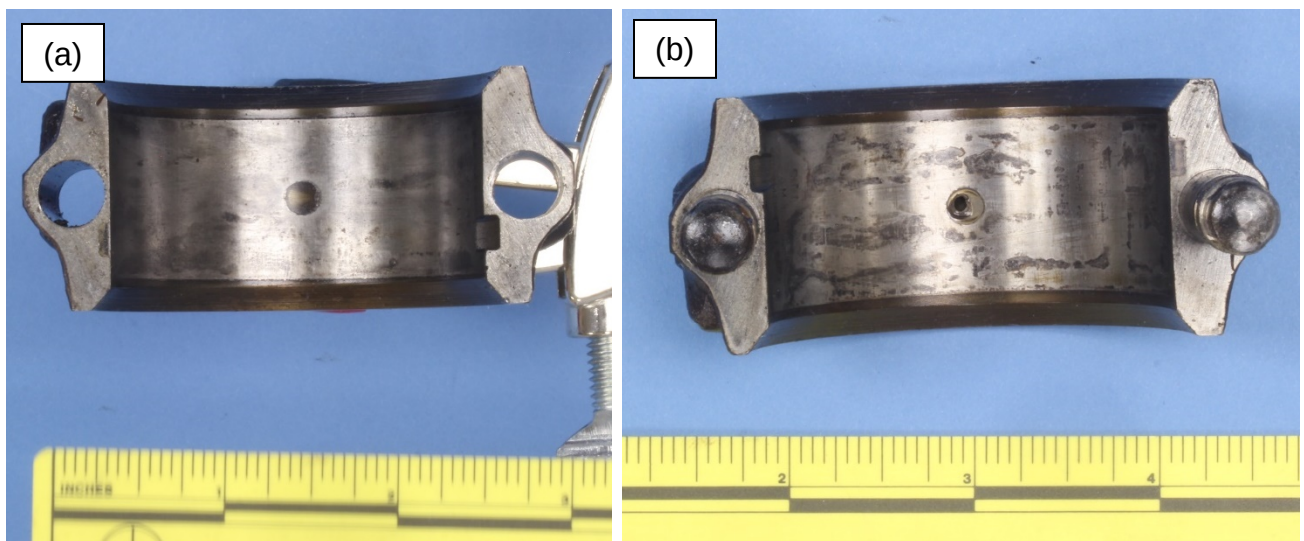


Figure 4 – The bearing surfaces of the connecting rod assembly from (a) the rod side and (b) the cap side.



Figure 5 – The piston, as received, from (a) the underside and (b) the pin hole bore side.

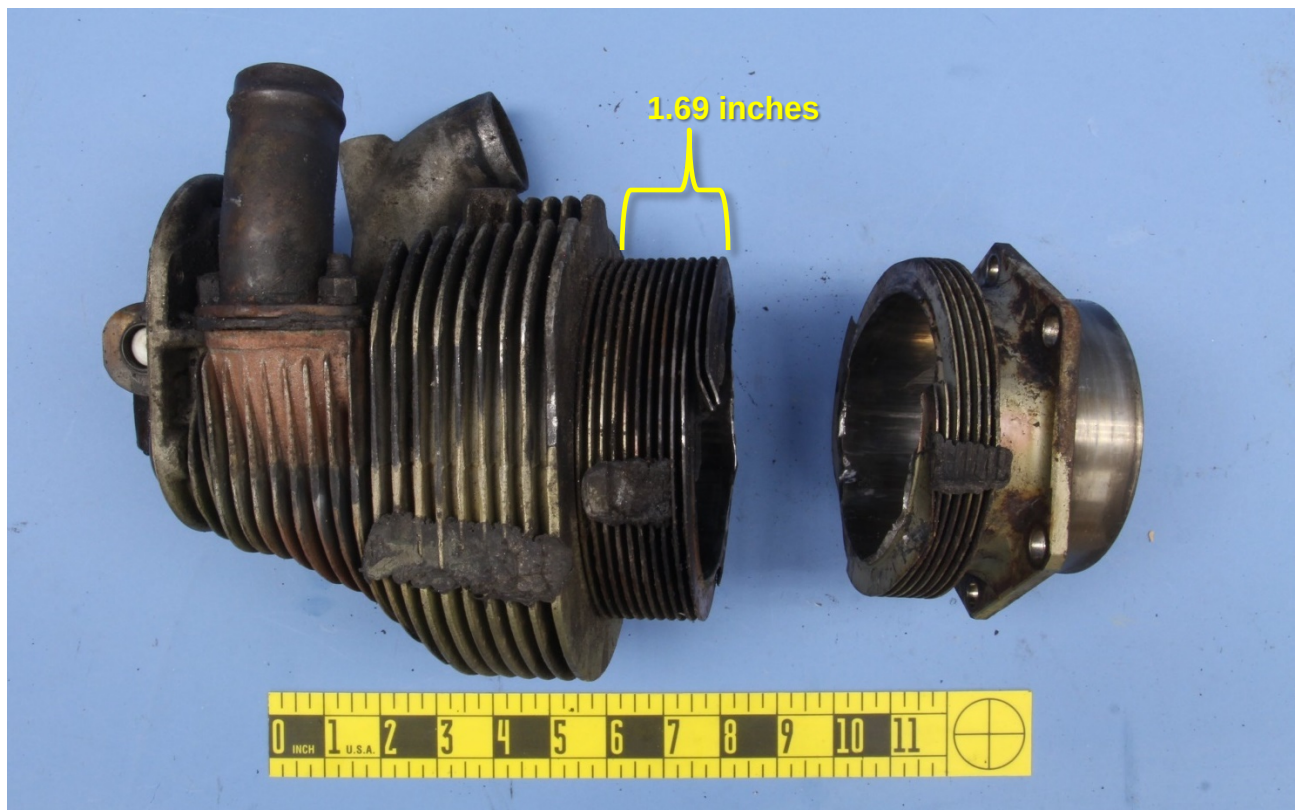


Figure 6 – The separated halves of the cylinder, as received.



Figure 7 – The cylinder, as received, showing the mating fracture surfaces.



Figure 8 – The valve side of the cylinder, showing the fractured cylinder wall. The fatigue crack region is highlighted.



Figure 9 – Closer view of the fatigue crack wall of the cylinder from the on the valve-side half.



Figure 10 – Closer view of the initiation region of the cylinder fatigue crack, after sectioning and cleaning.



Figure 11 – Closer view of the initiation region from Figure 10.

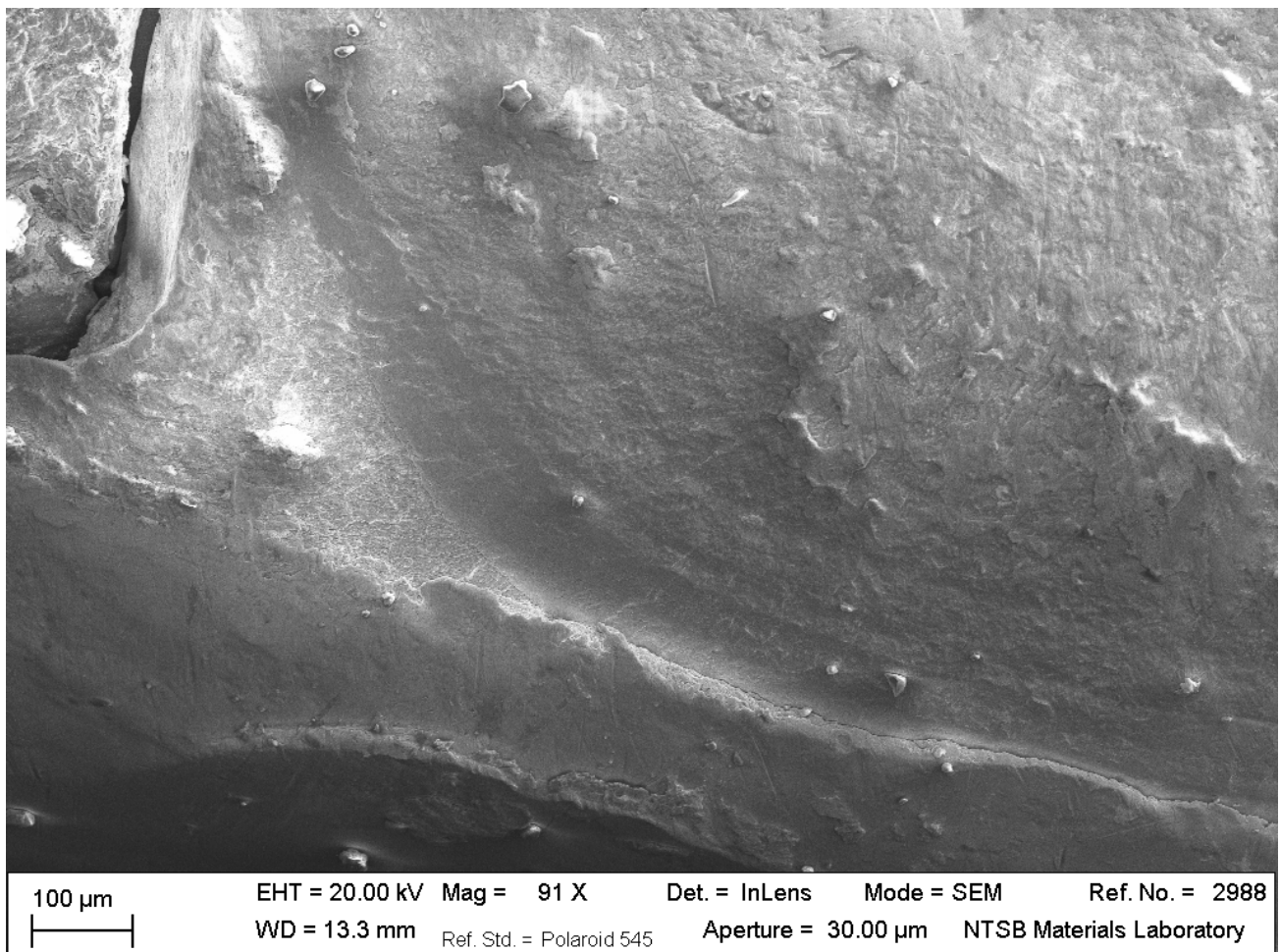


Figure 12 – Secondary electron (SE) micrograph of the end of the fatigue crack.

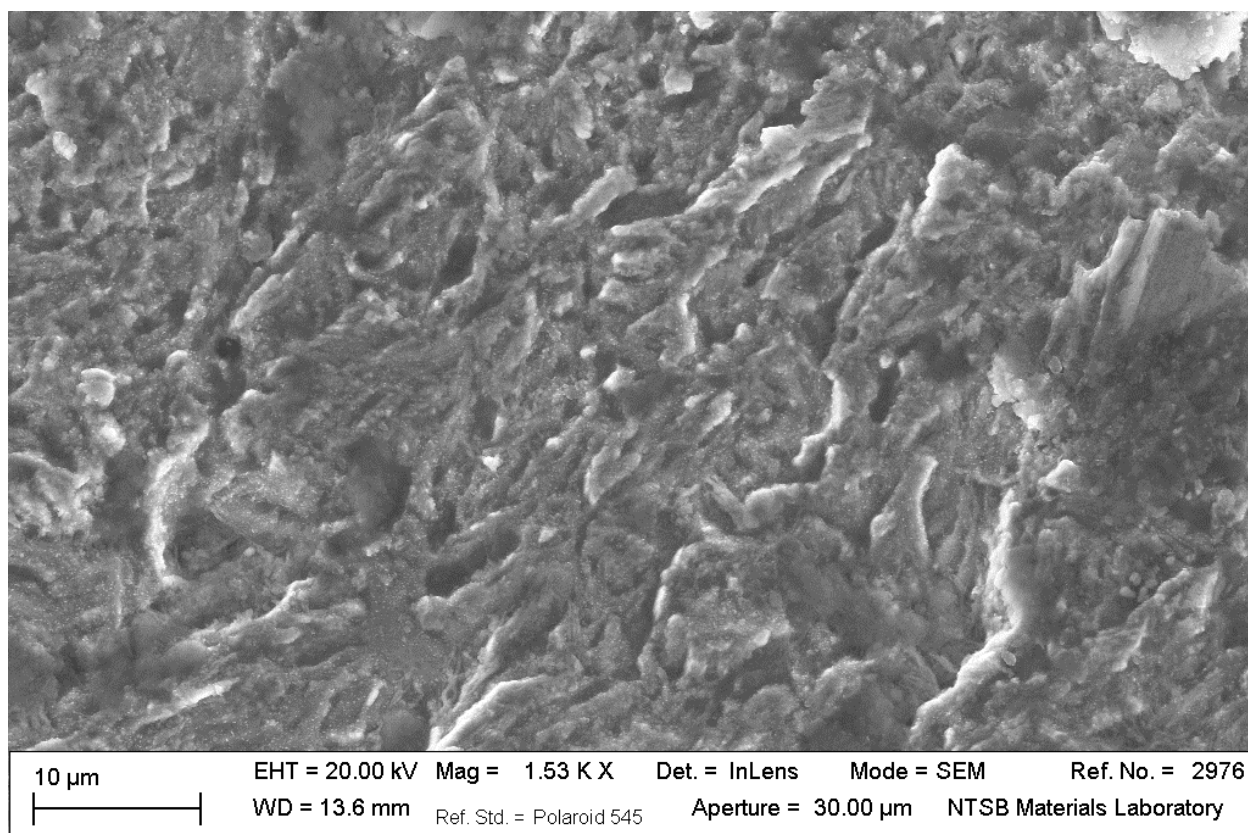


Figure 13 – SE micrograph of the fatigue region, showing striations.

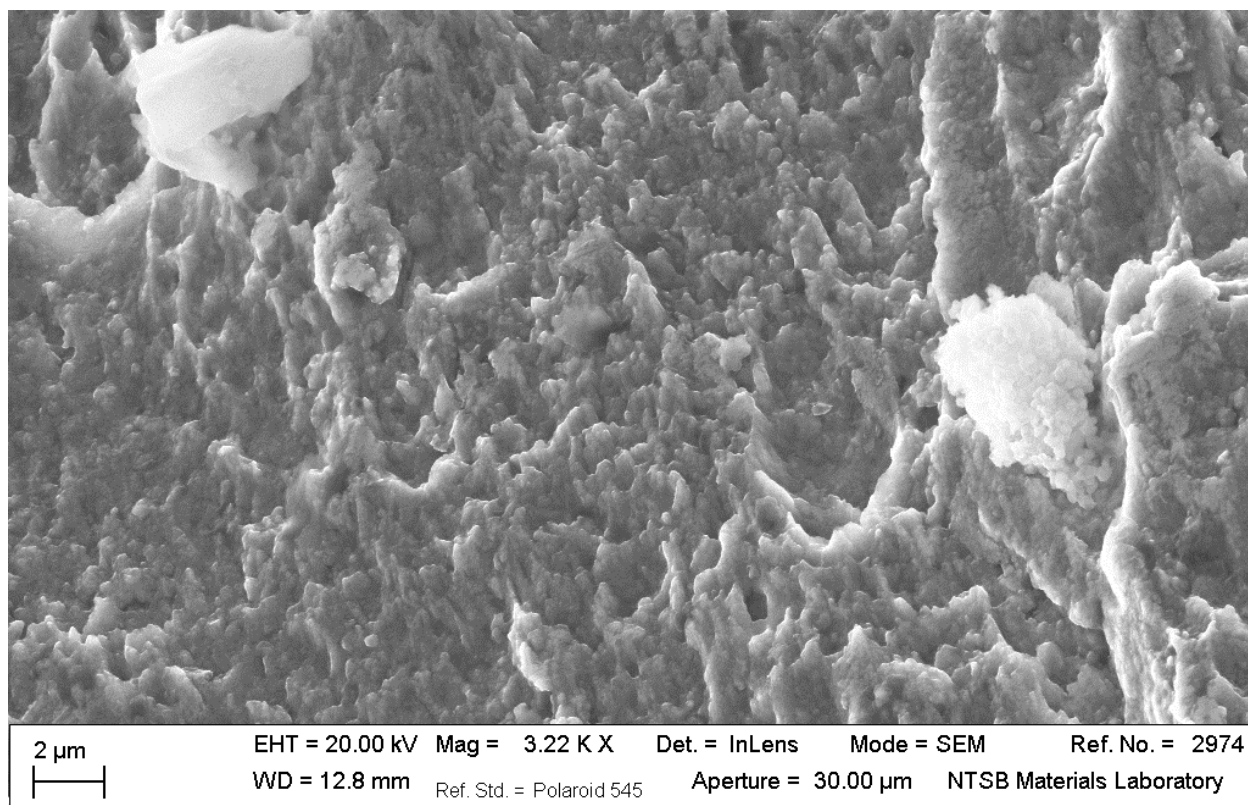


Figure 14 – SE micrograph of dimple rupture outside the fatigue region on the fracture.

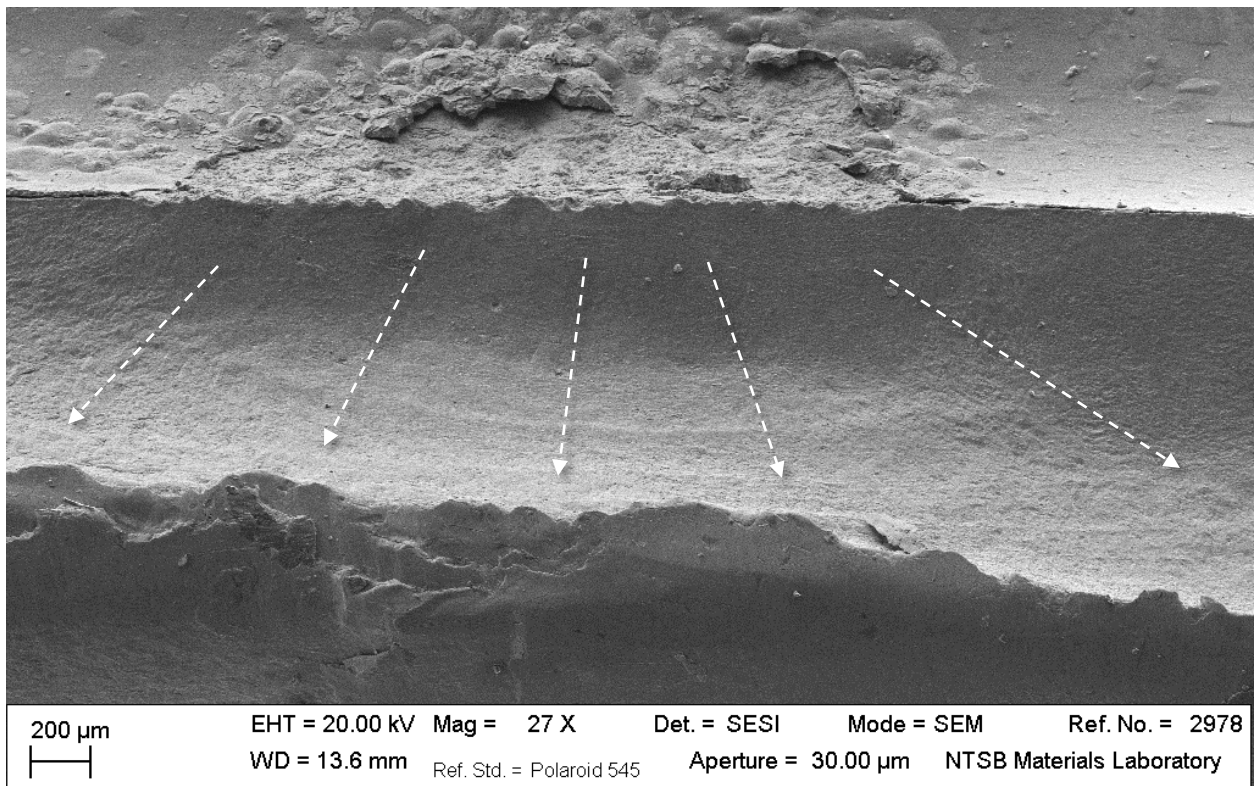


Figure 15 – SE micrograph showing the fatigue crack initiation site.

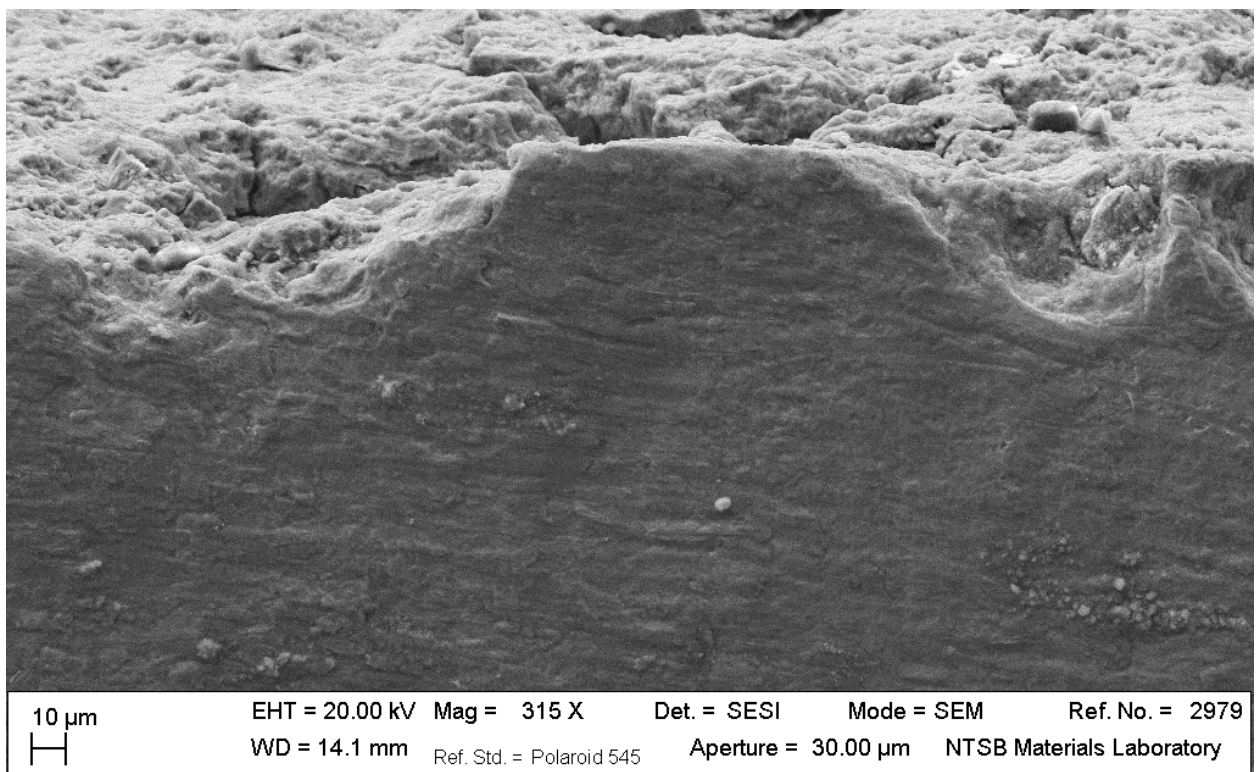


Figure 16 – SE micrograph of the fatigue crack initiation site, showing corrosion pits.

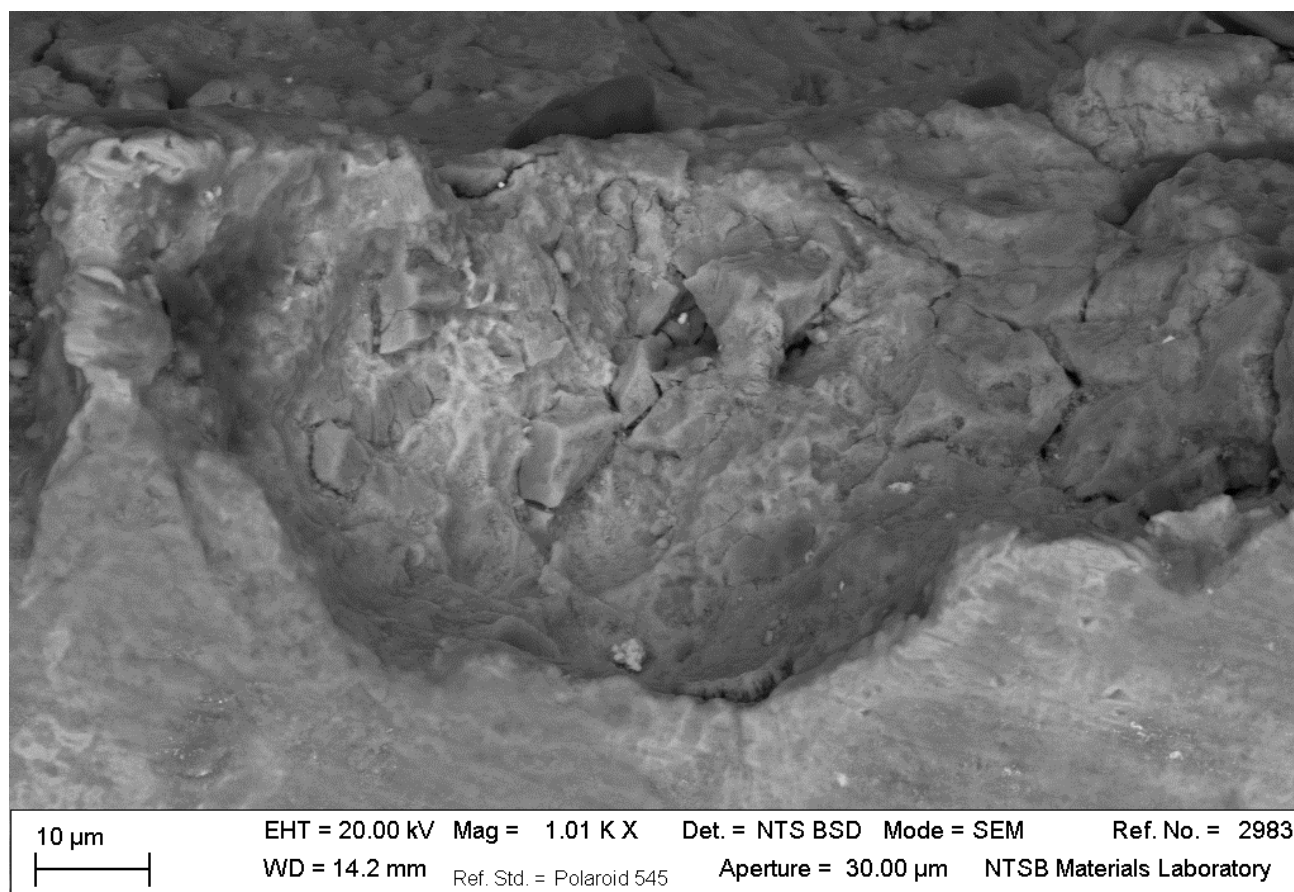


Figure 17 – Backscattered electron (BE) micrograph closeup of the corrosion pit at the fatigue crack initiation site.

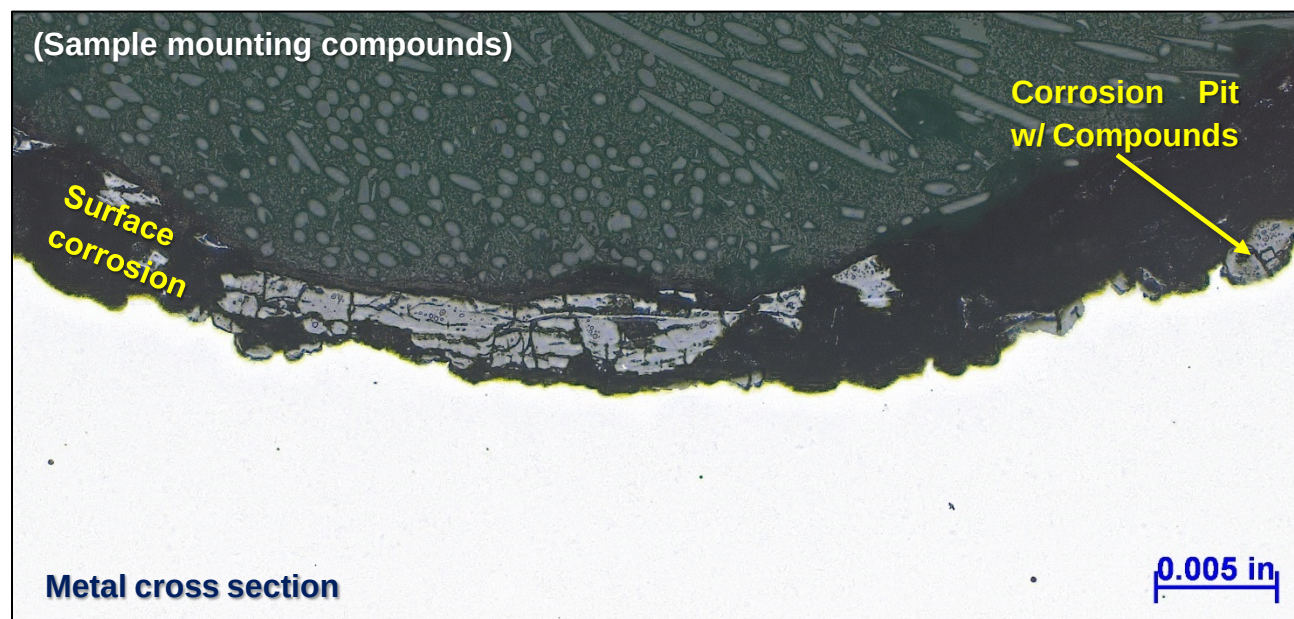


Figure 18 – Bright field (BF) optical micrograph of a cross section of the cylidner wall, showing corrosion and pitting at a cooling fin root (~100X, as polished).

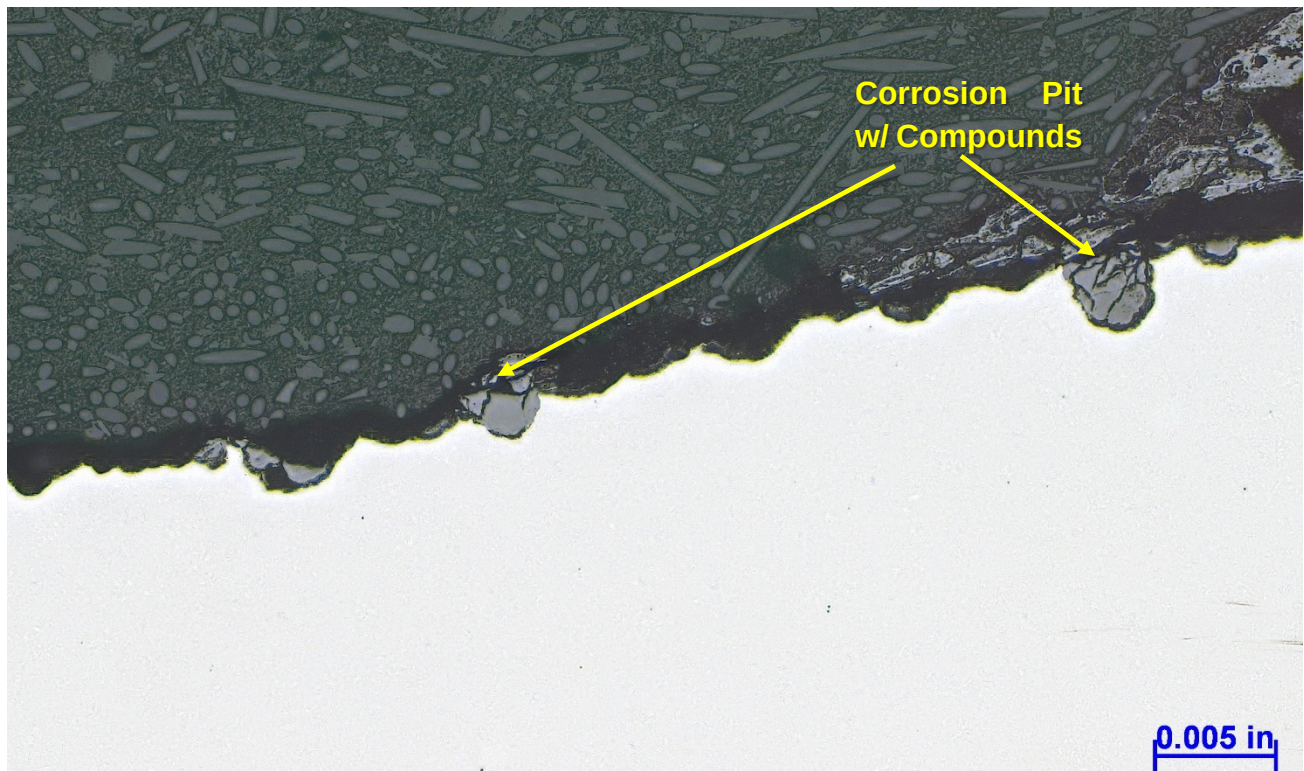


Figure 19 – BF optical micrograph of a cylinder wall cross-section showing corrosion pits along a fin (~100X, as polished).

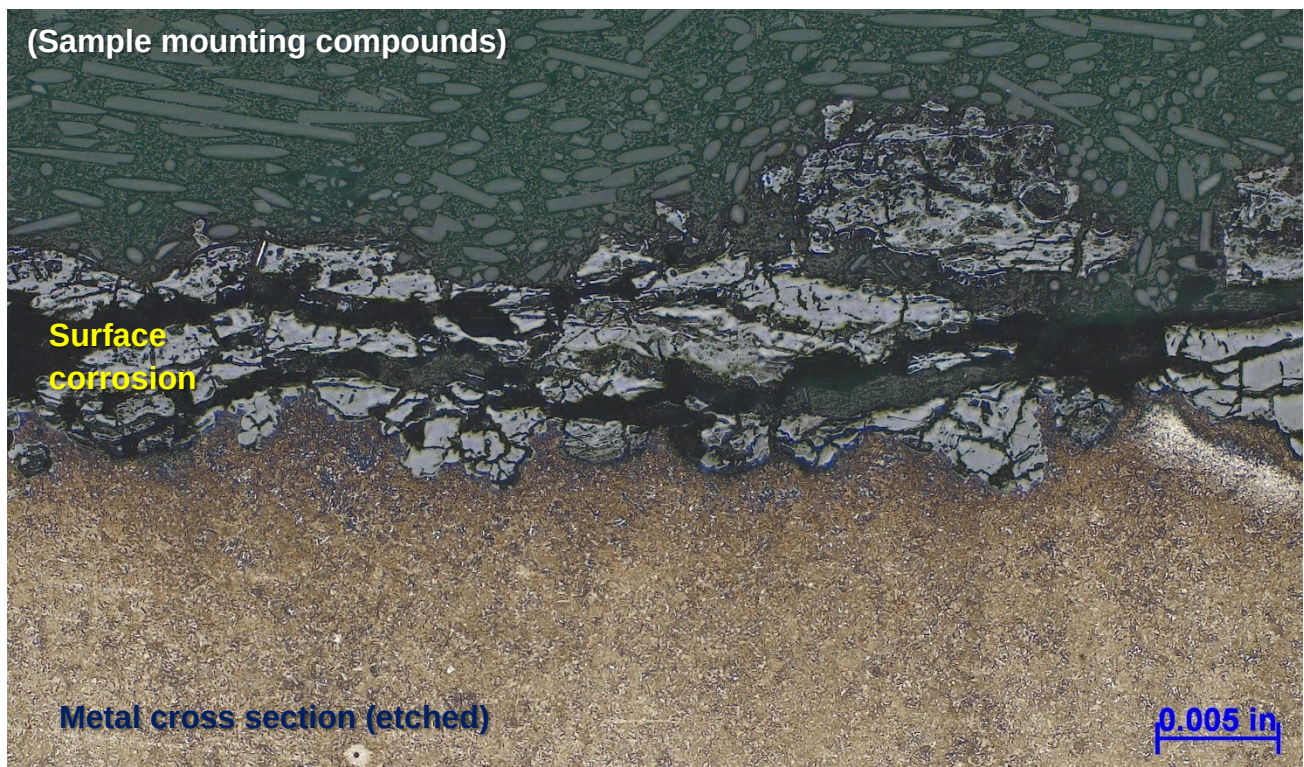


Figure 20 – BF optical micrograph highlighting surface corrosion and pitting on the cylinder (~100X, etched 2% Nital).

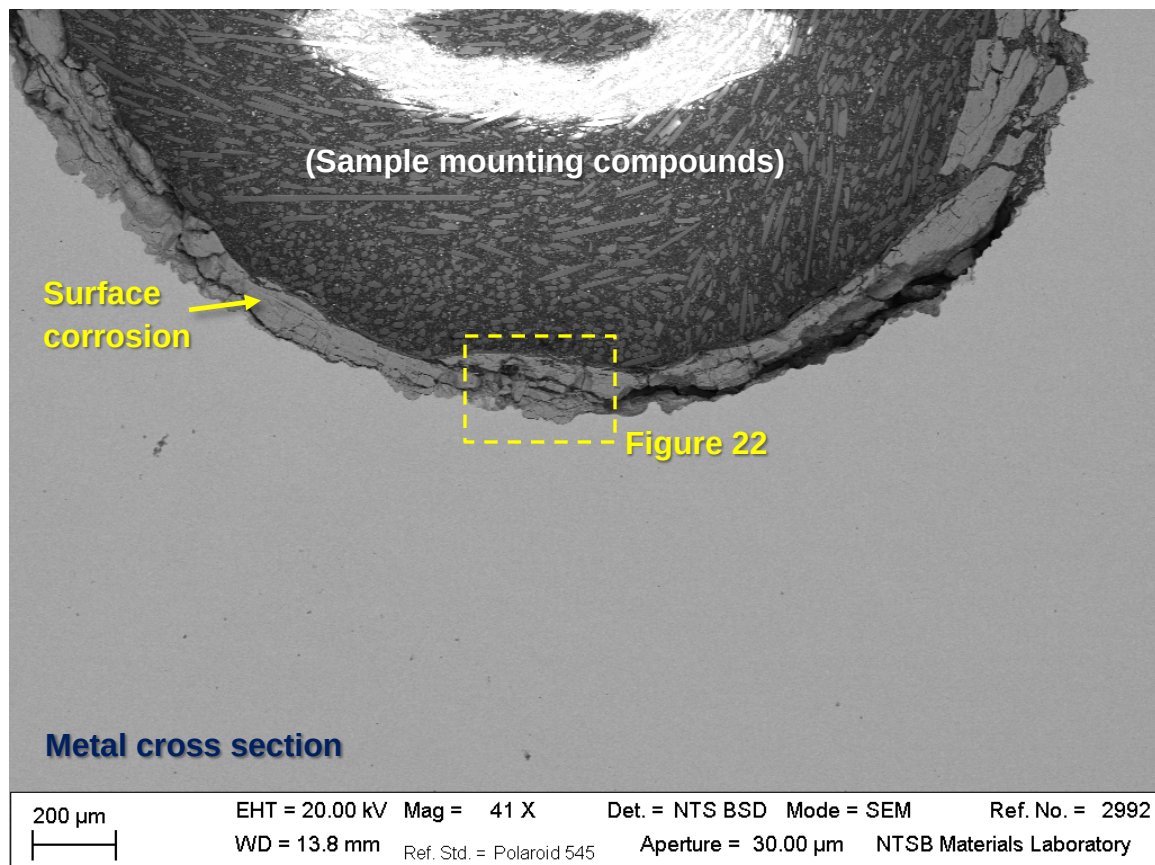


Figure 21 – BE micrograph showing corrosion and pitting at the cylinder fin root in Figure 18. The boxed area is highlighted in Figure 22.

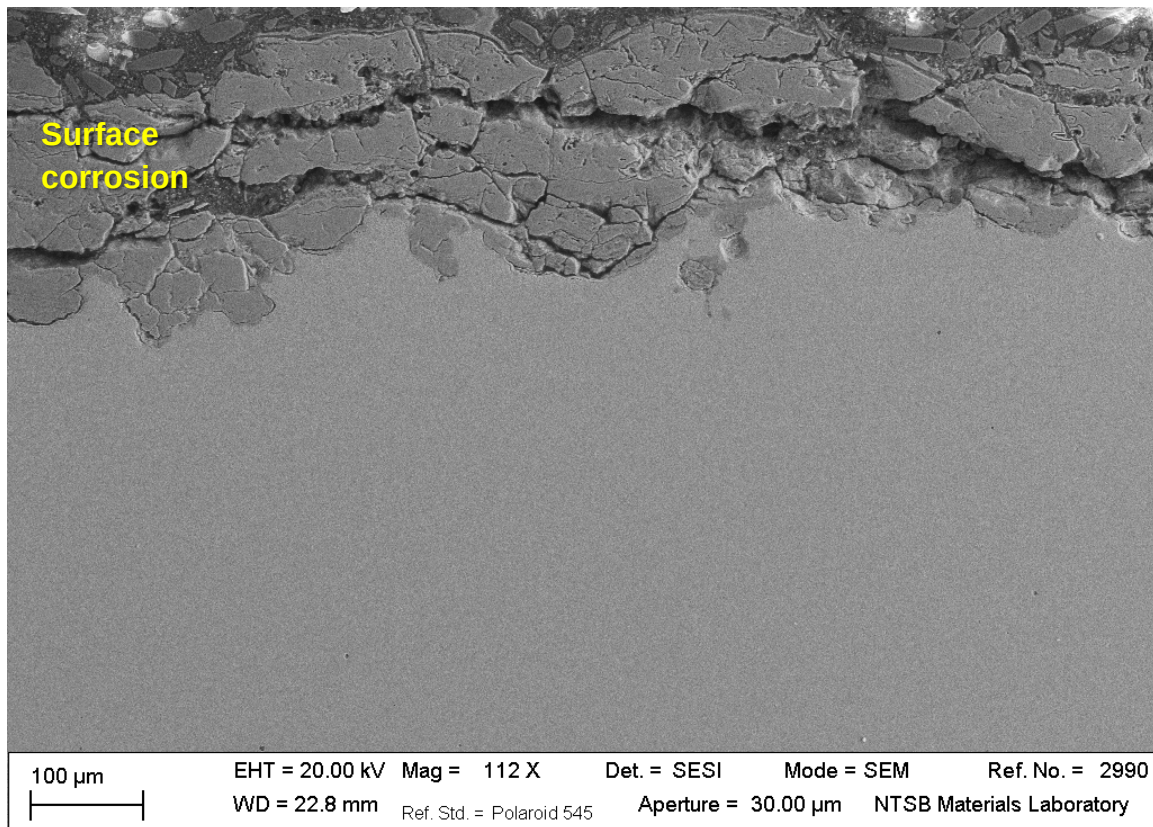


Figure 22 – BE micrograph showing a closer view of pitting and corrosion in Figure 21.

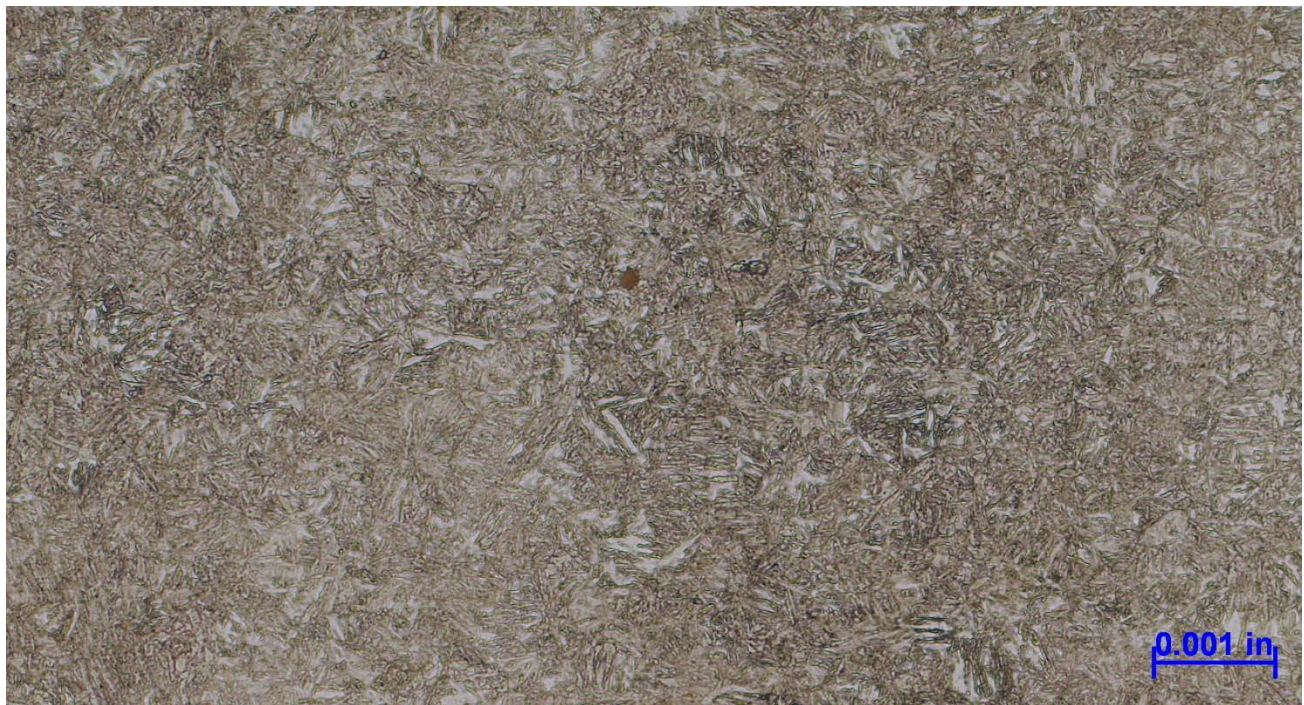


Figure 23 – BF optical micrograph showing the cylinder wall microstructure, consistent with tempered martensite (~500X, etched 2% Nital).