

NATIONAL TRANSPORTATION SAFETY BOARD

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



April 19, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 18-027

1. ACCIDENT INFORMATION

Place : Westphalia, Kansas
Date : September 29, 2017
Vehicle : Piper PA-25-235, N7336Z
NTSB No. : CEN17LA372
Investigator : Aaron Sauer, AS-CEN

2. COMPONENTS EXAMINED

Fractured halves of crankshaft
Forward main journal bearing halves

3. DETAILS OF THE EXAMINATION

On August 28, 2017, at 1716 central daylight time, a Piper PA-25-235 airplane impacted terrain following a loss of engine power near Westphalia, Kansas. The commercial pilot, who was the sole occupant, was not injured, and the airplane sustained substantial damage. According to the Federal Aviation Administration inspector who spoke to the pilot, after spraying a field for about 20 minutes, the engine lost power. While in a forced landing, the airplane stalled and impacted terrain. The airplane engine was a Lycoming O-540 series.¹ Several components from the engine were sent to the NTSB Materials Laboratory for further examination.

Figure 1 shows the fractured engine crankshaft, as received. The crankshaft had fractured across a web located between the second cylinder (C2) journal and the second main (M2) journal. A closer view of this fracture is depicted in Figure 2. The mating faces of this fracture surface are illustrated from the aft and forward sides in Figure 3 and Figure 4, respectively. The diameters of these journals were measured using digital Vernier calipers. The data are compiled in Table 1.

The fracture surface exhibited some smearing and rubbing damage, consistent with post-fracture contact, as exemplified in the upper left and right portions of Figure 3 and Figure 4. Approximately 60% of the fracture surface exhibited a generally flat portion with

¹ The O-540 is a family of air-cooled six-cylinder, horizontally opposed engines made by Lycoming Engines, headquartered in Williamsport, PA.

crack arrest marks. These crack arrest marks appeared to emanate out from near the corner of the web near the M2 journal, as shown in Figure 3.

The forward face of the crankshaft web fracture surface was sectioned and cleaned using acetone (displayed in Figure 4). A closer view of the crack initiation site, from where the crack arrest marks progressed, is shown in Figure 5 and Figure 6. The crack arrest features were not consistent with having progressed from a surface or from an internal feature, such as a lubrication hole or a sludge plug. Rather, as shown in Figure 6, the fracture features were consistent with a subsurface crack initiation.

The forward fracture surface of the crankshaft was examined using a scanning electron microscope (SEM). Figure 7 and Figure 8 show typical features from areas near the crack initiation site and near the end of the crack, respectively. These figures show fatigue striations, consistent with fatigue crack propagation. The fatigue striations increased in spacing during propagation (compare Figure 7 at 5430X magnification and Figure 8 at 2150X magnification). The spacing and morphology of the striations, particularly near the initiation site, were consistent with high-cycle fatigue in this alloy.

The chemical composition of the crankshaft was examined using energy dispersive x-ray spectroscopy (EDS). The composition was consistent with an alloy steel.

The fatigue crack initiation site is shown in Figure 9. Closer views of the initiation site are shown in Figure 10 through Figure 12. As shown in Figure 11 and Figure 12, the fatigue striations and crack arrest marks progressed out of a small ridge-like portion of the fracture surface (Figure 11). Much of this area was smeared consistent with post-fracture damage. Examination of this initiation site did not reveal any material defects such as inclusions or voids. As measured using the SEM, the fatigue crack initiation site was located 0.32 inches (0.822 mm) below the surface.

A portion of the forward fracture surface was cross-sectioned, mounted and polished. Figure 13 shows some of the cross-sectioned fracture surface, after etching with 2% Nital solution. There were no noted features adjacent to the fatigue crack initiation site. Note that the dark bluish colored regions near the fatigue crack initiation site cross section in Figure 13 were artifacts from overetching.

However, there was a noted darker region towards the external surface of the web piece (the left side of Figure 13). This darker region was consistent with a layer that had been case hardened (such as through a carburizing or nitriding surface treatment). The approximate depth of this layer was 0.03 inches.

This depth was consistent with the depth of the fatigue crack initiation site. Figure 14 shows a closer view of the microstructures from both those regions. In comparing Figure 14a and Figure 14b, the case-hardened region exhibited a darker contrast, consistent with higher carbon or other interstitial-strengthening element content. The tempered martensite microstructure was typical for those observed in examining alloy steels.

The forwardmost main bearing journal (M1) is shown from opposite sides in Figure 15 and Figure 16, as received. Of most note was the discoloration and dark circumferential wear marks on the aft most two inches. Figure 17 shows the inner bearing surfaces of the forward thrust bearings placed near the M1 journal, in their positions during service. The upper and lower bearing in Figure 17 were labeled bearing A and bearing B for the purposes of this report. The markings on the outside of both Bearing A and Bearing B stated, "AEL13884M006, REV K H0, FAA-PMA".

Figure 18 shows the internal surface of the aft side of bearing A. When compared to the inner bearing surface on the forward side (Figure 19), the aft side had been significantly more damaged. While both sides exhibited circumferential wear marks, consistent with rotational contact with the crankshaft, the aft side exhibited severe metal deformation of the underlying material. This material was smeared outside of the inner surface, as shown in Figure 20. Closer examination of the aft bearing surface revealed spalling, displacement, and cracking consistent with bearing wear fatigue (Figure 21).

These features were amplified on the inner surfaces of Bearing B (Figure 22 and Figure 23). While the forward surface exhibited some minor rotational wear, the aft bearing surface exhibited spalling, material displacement, and smearing. Much of this spalled and smeared material was found accumulated in the lubrication groove, as shown in Figure 23. The material had cracked and deformed, as shown in Figure 24. All this bearing damage was typical of similar bearing that operated at elevated temperatures using inadequate lubrication.

Erik M Mueller
Materials Research Engineer

Table 1 – Diameters of various journals on the crankshaft, measured using digital calipers.

Journal	Journal Diameter (inches)	
M1 (Forward)	2.370	Crankshaft Forward
M1 (Aft)	2.367	
C1	2.116	
C2	2.118	
M2	2.367	
C3	2.118	
C4	2.118	
M3	2.370	
C5	2.118	Crankshaft Aft
C6	2.380	

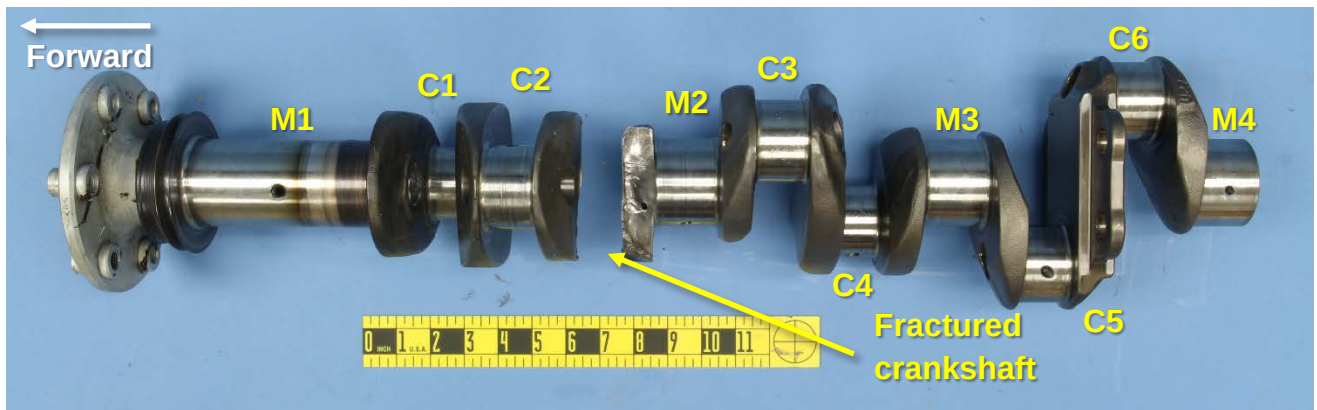


Figure 1 – The fractured crankshaft, as received. The part fractured at the web between the C2 and M2 journals, as labeled in the figure.

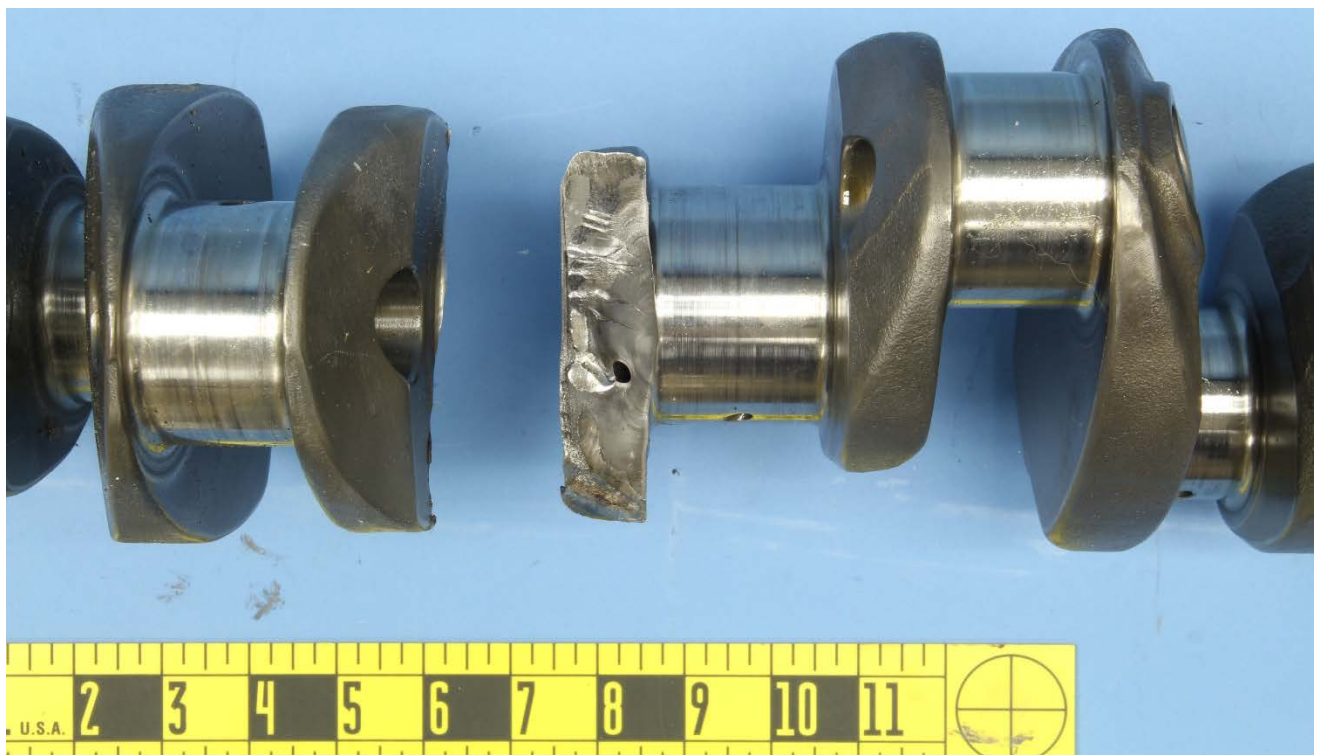


Figure 2 – Closer view of the mating fracture surfaces of the crankshaft, located at the web between the C2 and M2 journals.



Figure 3 – View of the aft mating fracture surface of the crankshaft, as received.



Figure 4 – View of the forward mating fracture surface of the crankshaft, after sectioning and cleaning with acetone.



Figure 5 – Closer view of the crack initiation site of the forward fracture surface in Figure 4.



Figure 6 – Closer view of the crack initiation site from Figure 5.

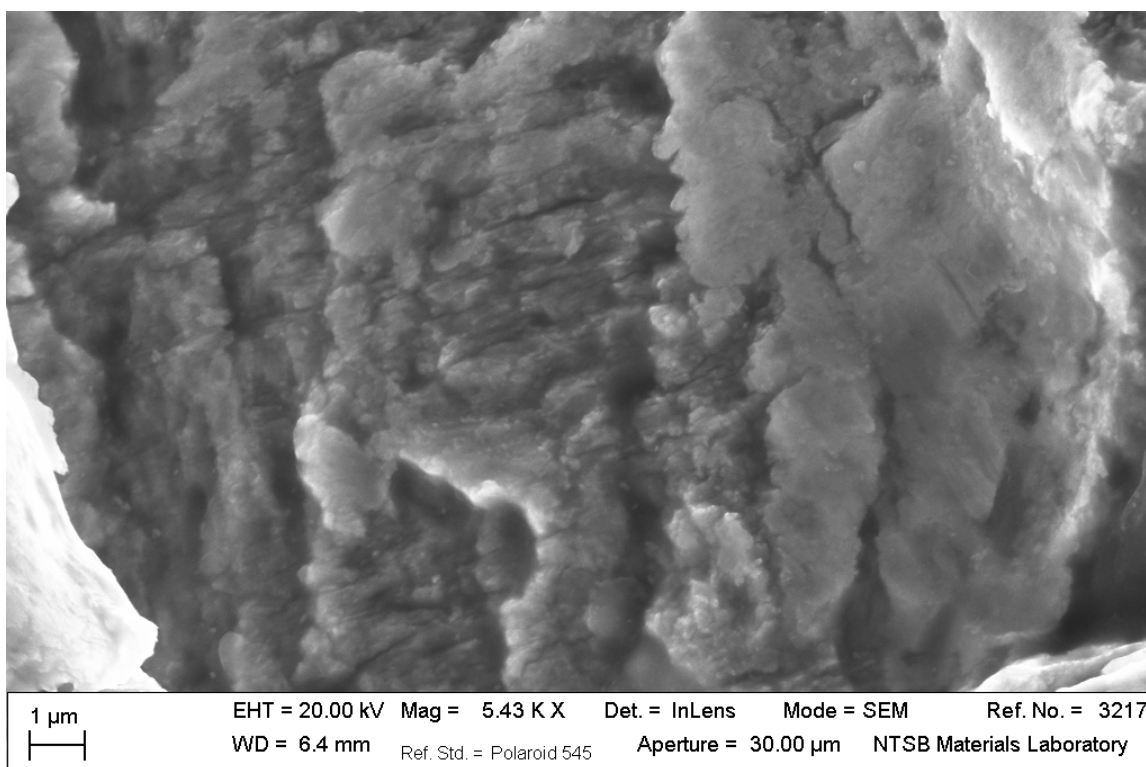


Figure 7 – Secondary electron (SE) micrograph of striations near the beginning of the fatigue crack.

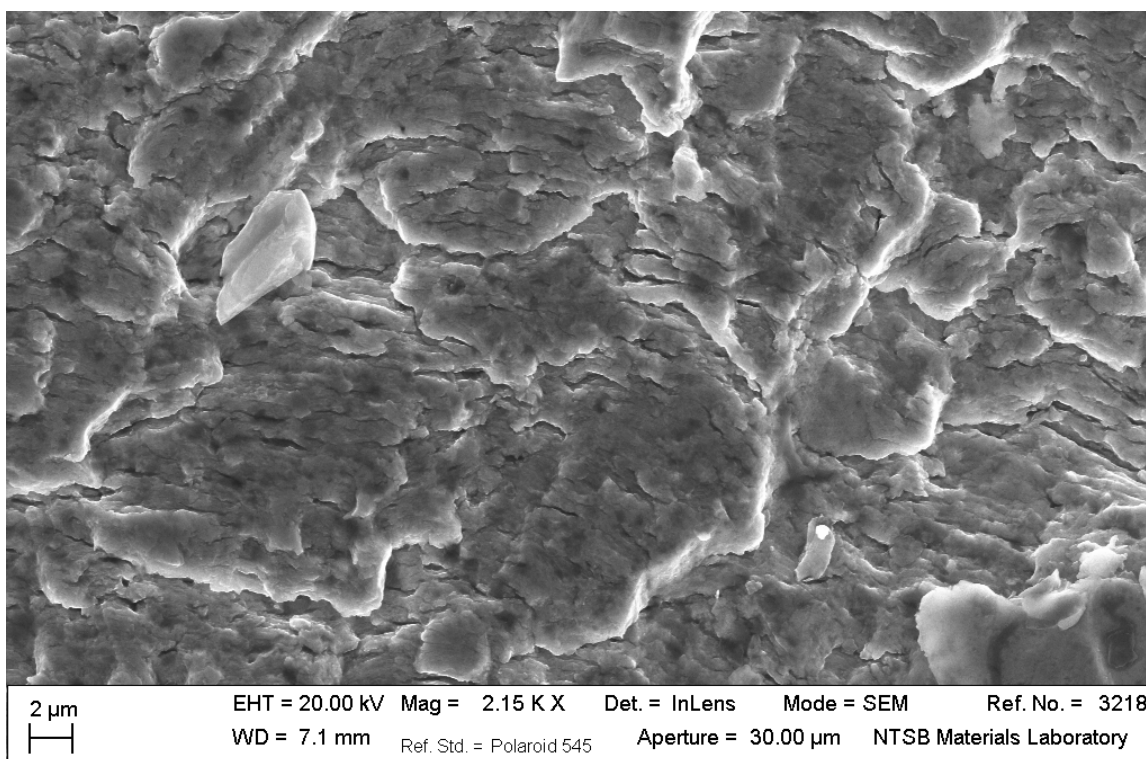


Figure 8 – SE micrograph of fatigue striations at the end of the fatigue crack.

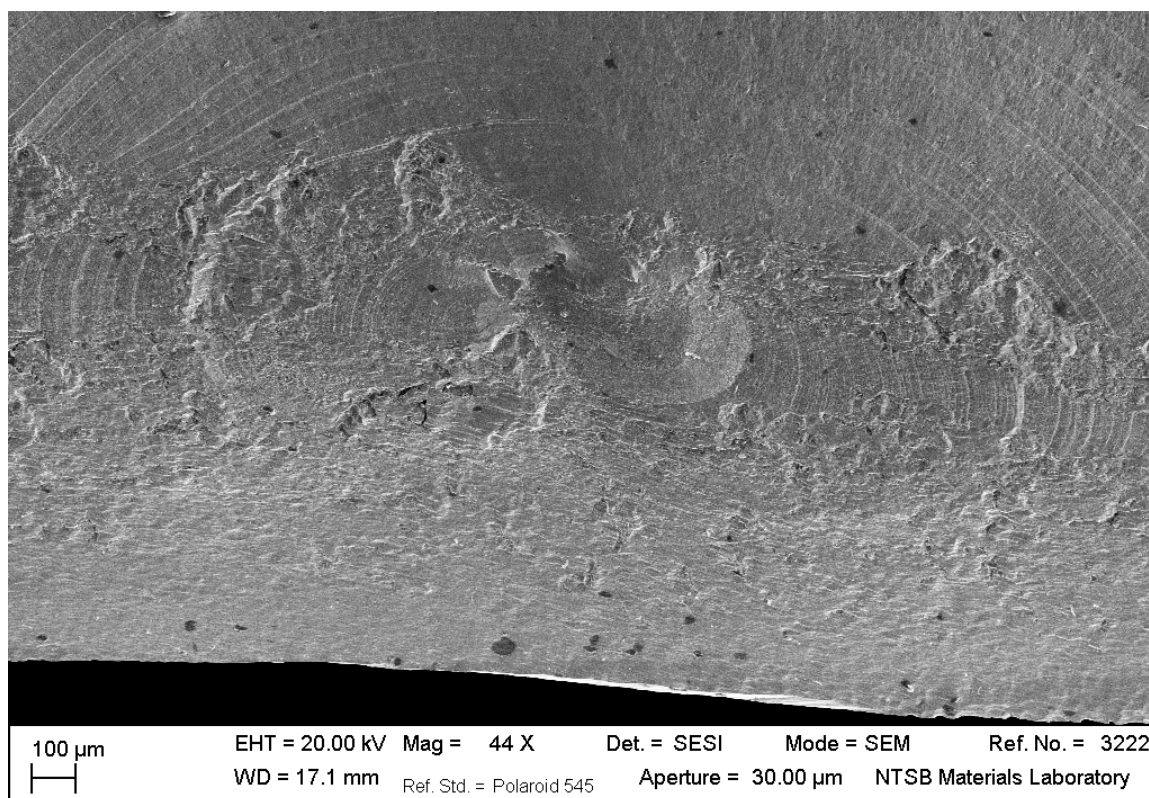


Figure 9 – SE micrograph of the fatigue crack initiation site, located 0.82 mm from the surface.

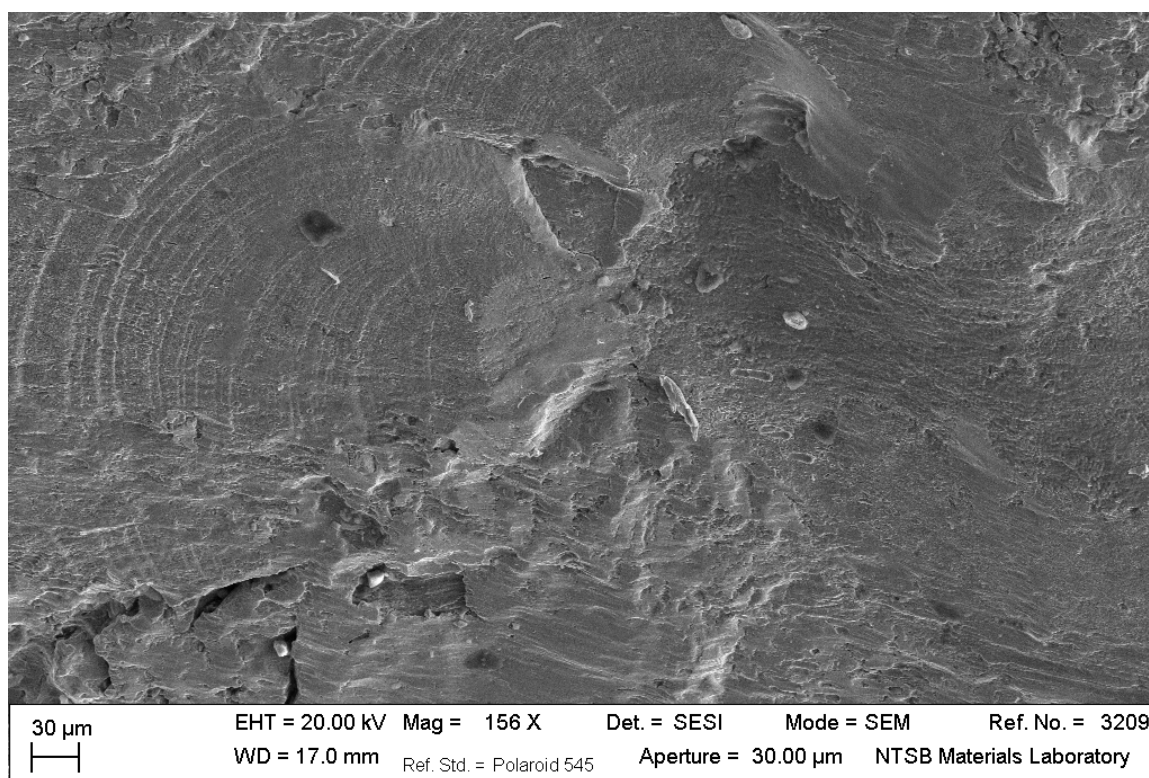


Figure 10 – SE micrograph of a closer view of the crack initiation site from Figure 9.

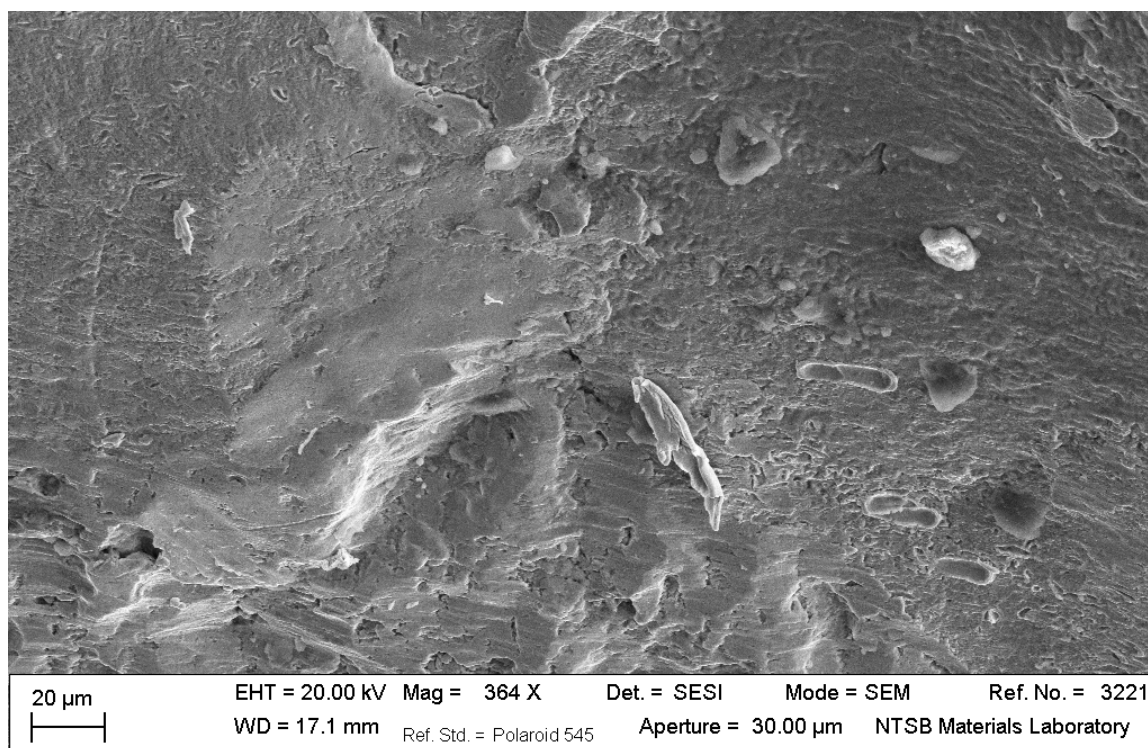


Figure 11 – SE micrograph of a closer view of the crack initiation site from Figure 10.

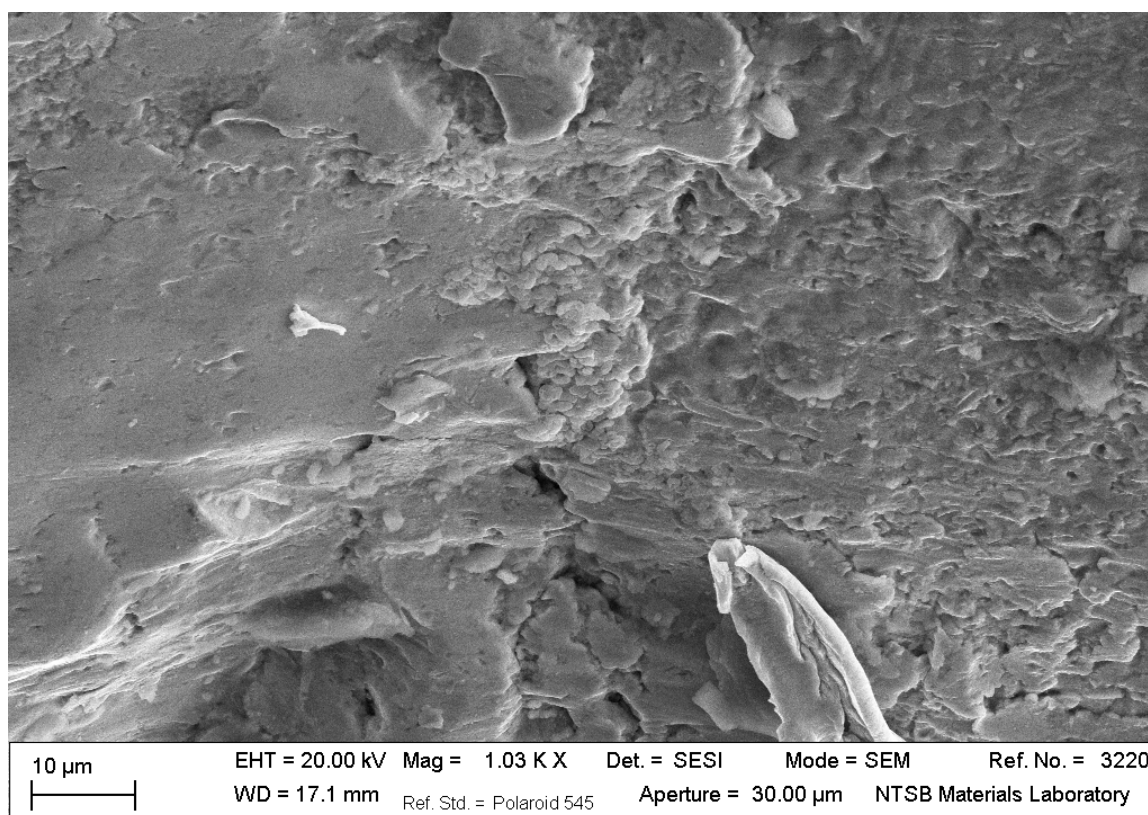


Figure 12 – SE micrograph of a closer view of the crack initiation site from Figure 11.

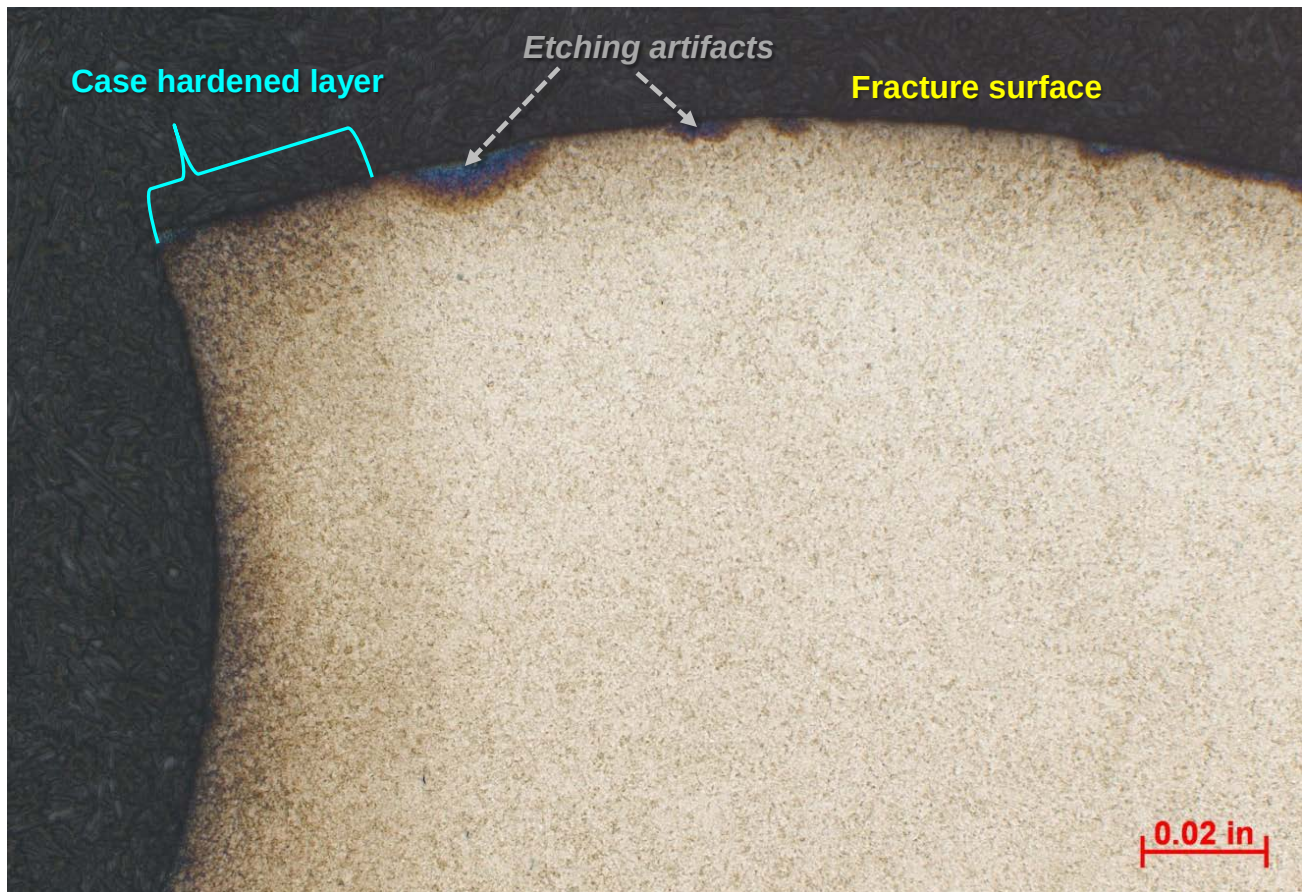


Figure 13 – Bright-field (BF) optical micrograph of a cross section of the fracture surface (~200X, etched 2% Nital).

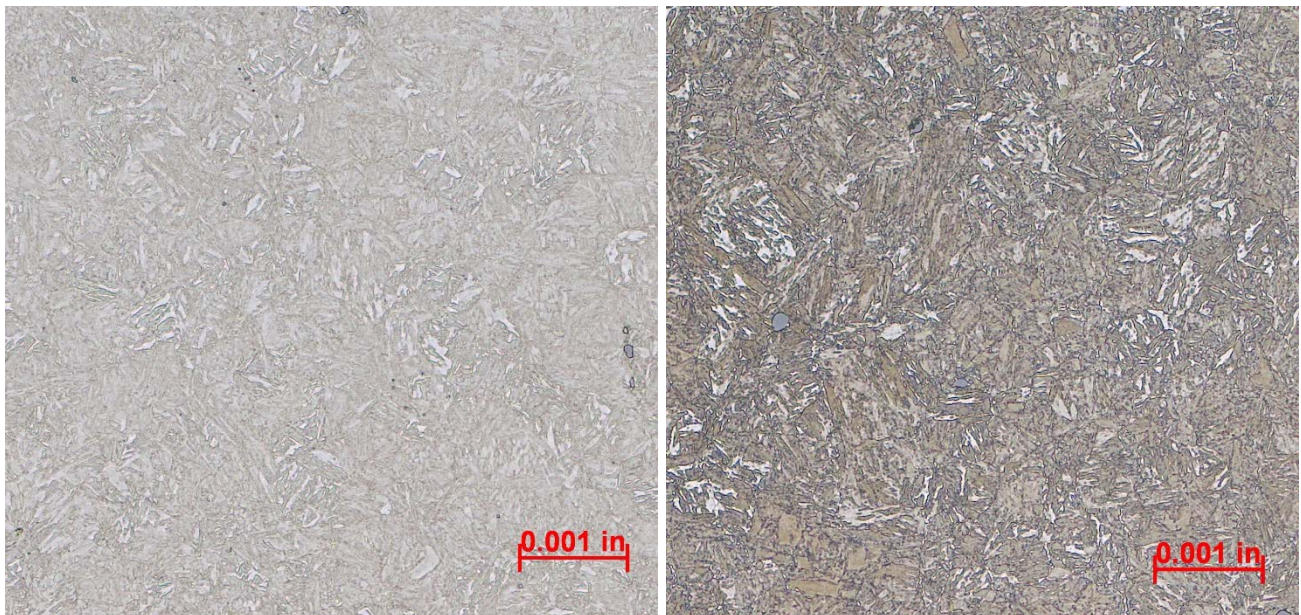


Figure 14 – BF optical micrograph of (a) a cross section of the bulk microstructure and (b) the microstructure near the surface, in the case hardened region (~500X, etched 2% Nital).

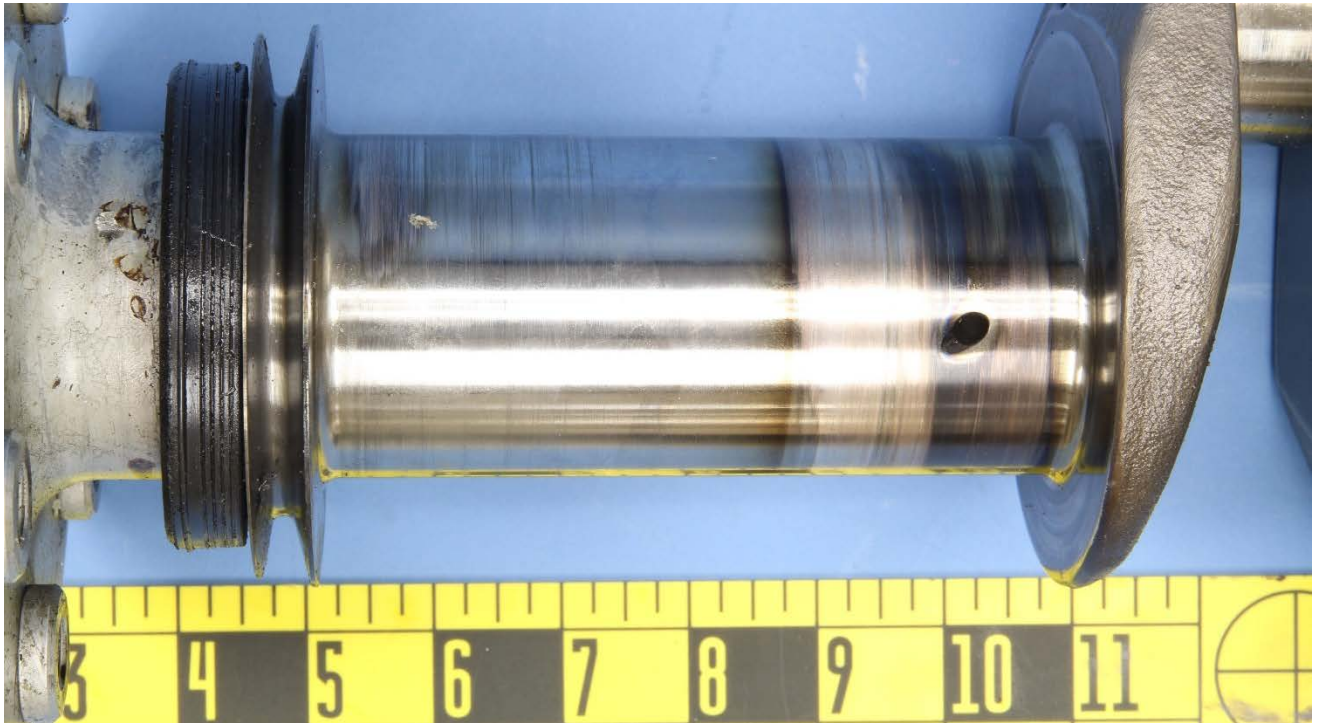


Figure 15 – The M1 crankshaft journal, as received, showing heat tinting and circumferential wear of the aft portion.

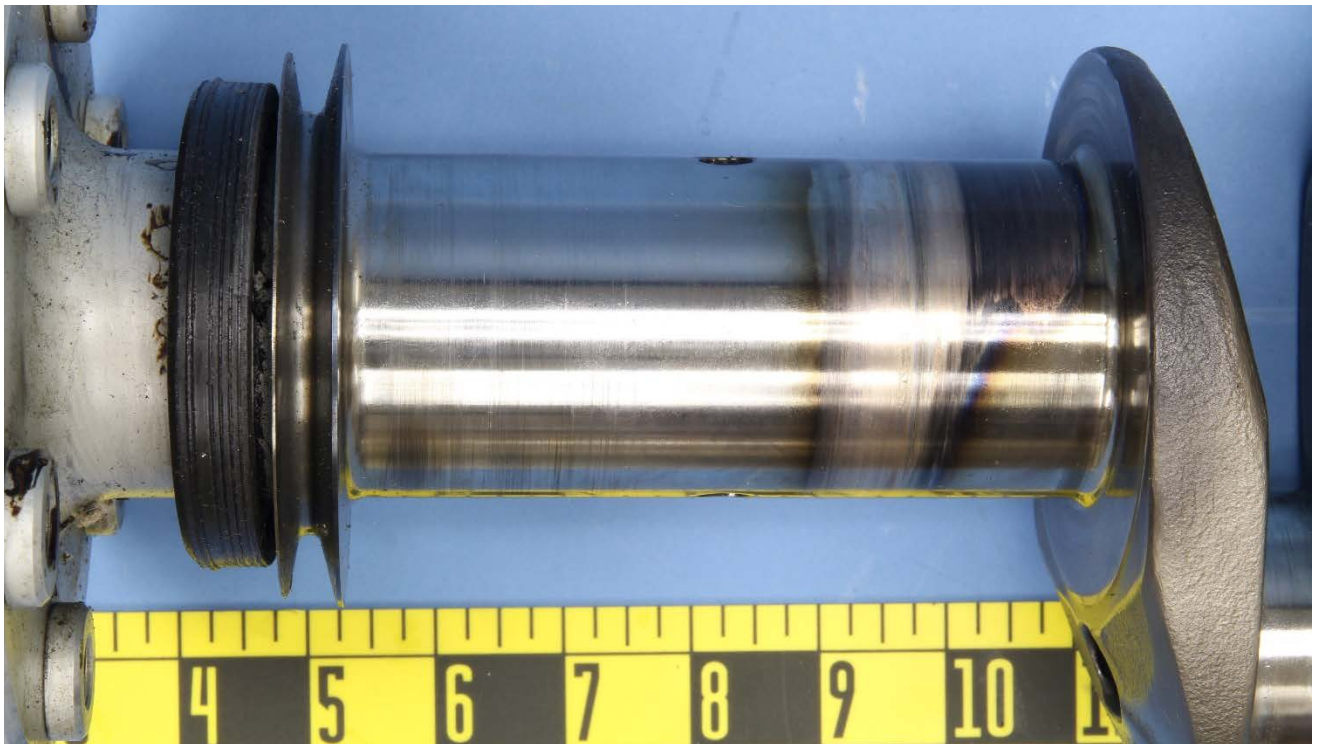


Figure 16 – The crankshaft M1 journal, rotated 180° from Figure 15.

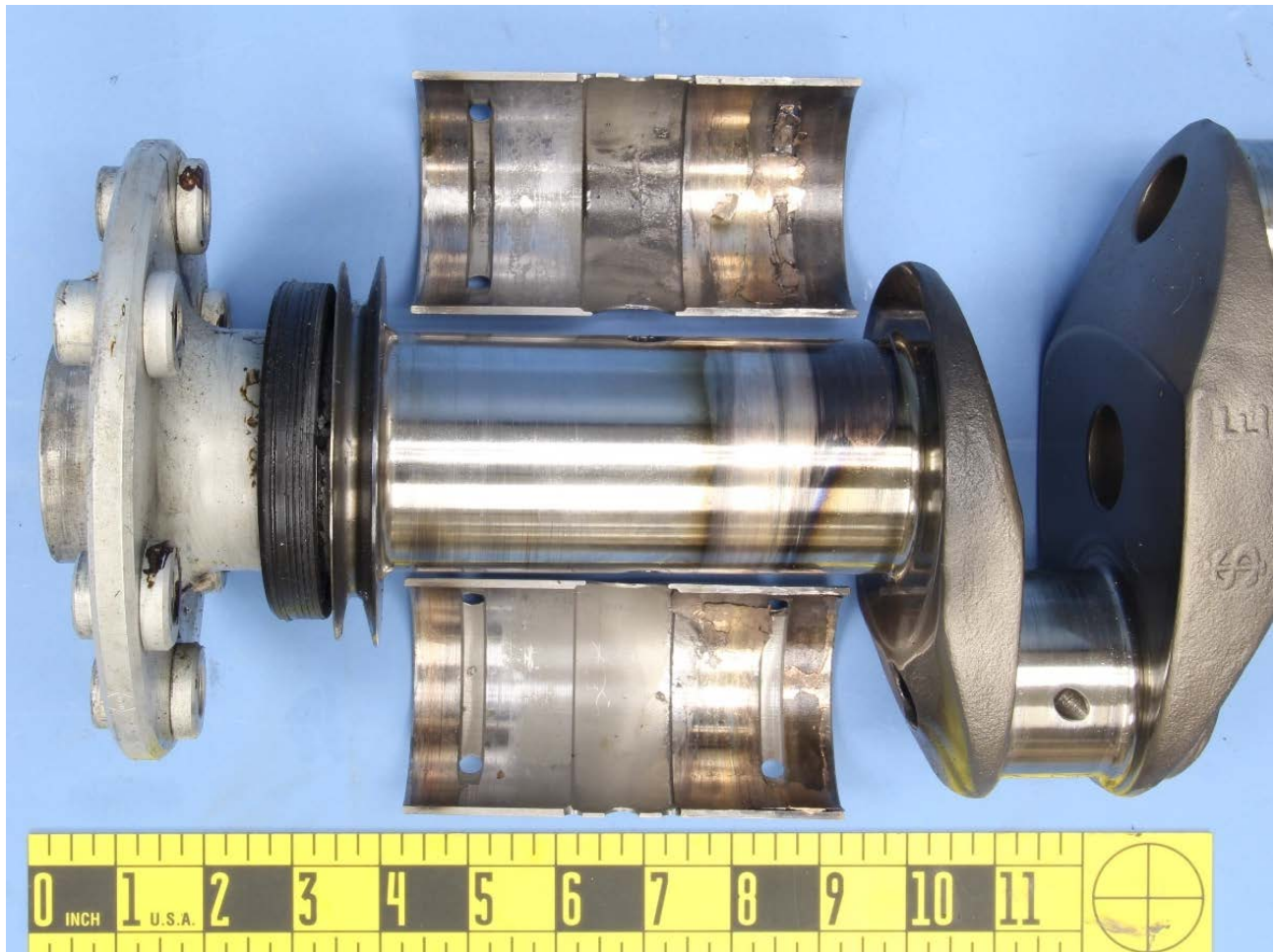


Figure 17 – The crankshaft M1 bearing journal, with the bearings placed next to the journal in the locations they were located during service. The damage on the aft side of the bearings was co-located with the damage to the crankshaft journal.



Figure 18 – The aft side of the internal surface of Bearing A, showing circumferential wear and material smearing and spalling.

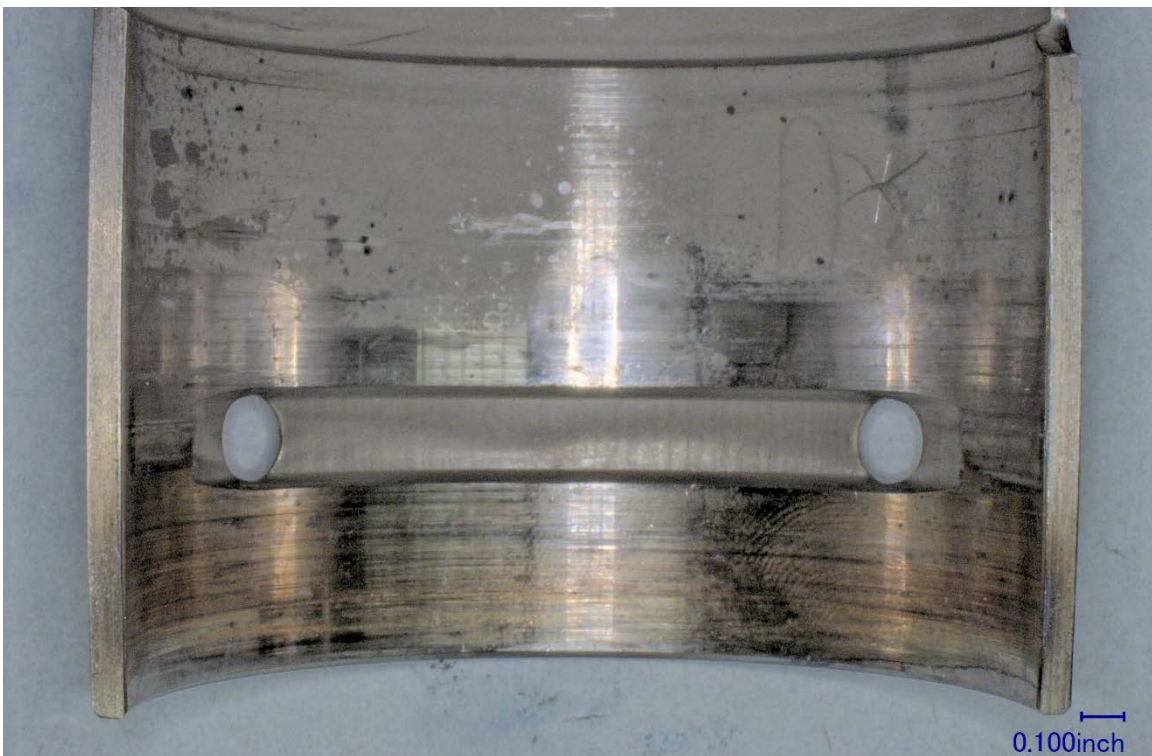


Figure 19 – The forward side of the internal surface of Bearing A.



Figure 20 – The side of aft portion of Bearing A, showing material smeared over the bearing edge.



Figure 21 – Closer view of the smearing damage, spalling, and fatigue cracking on the aft side of the Bearing A internal surface.

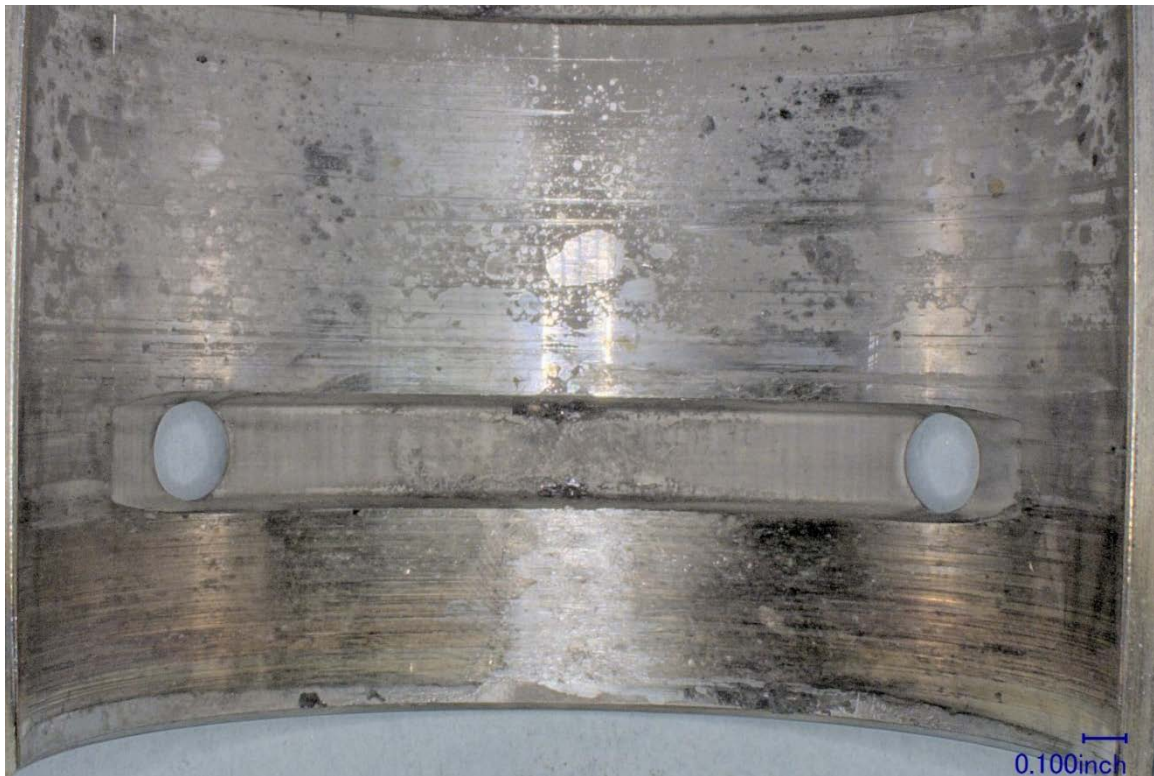


Figure 22 – The forward side of the internal surface of Bearing B.



Figure 23 – The aft side of the internal surface of Bearing B, showing circumferential wear and material smearing and spalling.

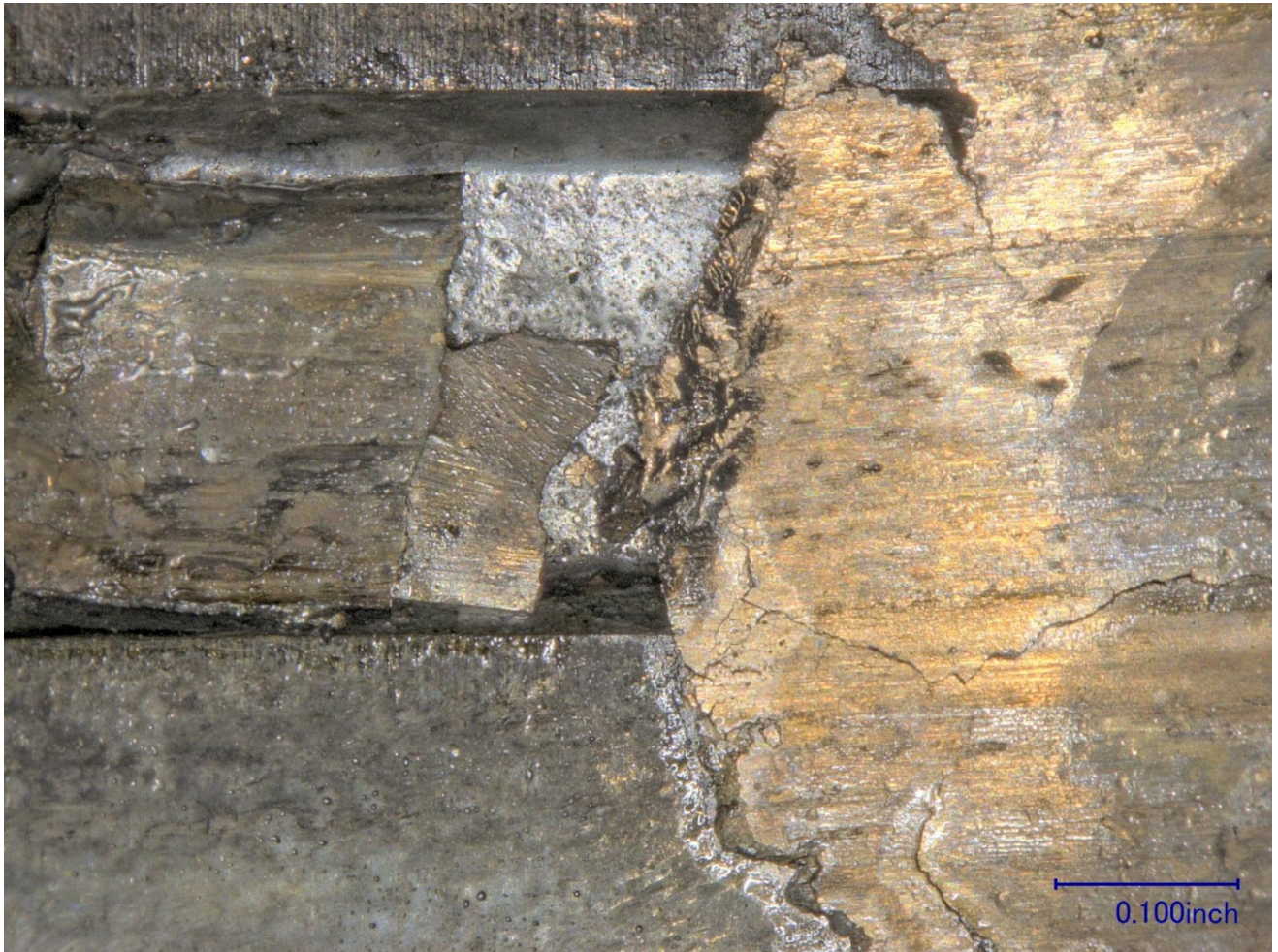


Figure 24 – Closer view of the smearing damage and spalling on the aft side of the Bearing B internal surface.