

NATIONAL TRANSPORTATION SAFETY BOARD

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



October 23, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 18-073

1. ACCIDENT INFORMATION

Place : Redding, California
Date : November 2, 2017
Vehicle : Cessna 172R, N2103T
NTSB No. : WPR18LA039
Investigator : Tealeye Cornejo, AS-WPR

2. COMPONENTS EXAMINED

Crankshaft
No. 1 connecting rod assembly
Main bearing halves
Pieces of flange

3. DETAILS OF THE EXAMINATION

On November 2, 2017, about 0930 Pacific standard time, a Cessna 172R was substantially damaged during an off-airport landing after the engine experienced a loss of power shortly after takeoff. The certified flight instructor and two students were not injured. According to the Federal Aviation Administration (FAA), about 3 miles from the airport, the pilot reported an engine failure with sparks coming from the engine. During the landing, the pilot crossed the runway and landed in a field. Several components from the Lycoming IO-360-L2A engine were recovered and sent to the NTSB Materials Laboratory for additional examination.¹

The components from the engine are shown in Figure 1, as received. These included a crankshaft, a connecting rod and cap with two bolts, two bearings, three flange fragments. The crankshaft had fractured into two halves at the main bearing journal on the forward side, located 3.40 inches aft of the flanges located aft of the propeller flange (see Figure 2). The fracture consisted of two primary mating crack faces, one circumferential and one spiral through a lubrication hole.

¹ The Lycoming IO-360-L2A is a four-cylinder, fuel-injected, direct-drive, horizontally opposed, air-cooled, piston aircraft engine produced by Lycoming Engines, headquartered in Williamsport, PA.

The circumferential fracture ran a lateral distance of 1.3 inches along the length of the main journal. The forwardmost part of the circumferential fracture was located 0.772 inches aft of the lubrication hole (Figure 3). Figure 4 shows the mating faces of the circumferential fracture. The fracture surfaces exhibited features such as crack arrest marks, indicative of progressive fracture, later determined to be fatigue. As annotated with white dashed arrows in Figure 4a, the crack arrest marks had propagated from the spiral fracture. The areas outside the fatigue crack exhibited features consistent with subsequent overstress fracture.

Figure 5 shows the forward portion of the crankshaft main journal, after sectioning from the forward part of the crankshaft. The spiral fracture was located across the lubrication hole depicted in Figure 5. The journal section was cut longitudinally 180° from the position shown in Figure 5. The opened spiral fracture is illustrated in Figure 6. These mating fracture surfaces exhibited crack arrest marks, consistent with progressive crack growth. No features consistent with other fracture modes were observed on these surfaces.

Closer views of the mating fracture surfaces are shown in Figures 7 through 10. On both mating surfaces, the crack arrest marks emanated from the lubrication hole. The sludge tube was still in place on one of the fracture surface holes (Figure 8). The tube exhibited deformation consistent from compressive crushing in the direction of the fracture.

The section of the spiral fracture surface about the lubrication hole was excised and cleaned, as depicted in Figures 9 and 10. The lubrication hole had been chamfered to allow seating of the tube lip. The hole exhibited witness marks consistent with rotational wear. As shown in Figure 10, the crack arrest marks originated from the inside portion of the hole walls.

The fracture surface was examined using a scanning electron microscope (SEM). While much of the fracture surface exhibited smearing, consistent with post-fracture contact and rubbing, fatigue striations were observed on undamaged portions. Figures 11 and 12 show fatigue striations at different magnifications. The varied size of the fatigue striations was consistent with spectrum (or non-uniform) loading of the crankshaft as the crack propagated.

Figure 13 shows one of the fatigue crack initiation sites of the spiral fracture adjacent to the lubrication hole. Due to post-fracture damage, any observable features of the initiation site had been obliterated. Observation of the surface of the lubrication hole found three other cracks, in locations consistent with that of the spiral fatigue crack (the inside corner of the hole). One of these cracks is illustrated in Figure 14.

Based on these observed fracture features, the crankshaft fractured from a fatigue crack that initiated at a lubrication hole on the main journal, towards the inside surface of the crankshaft journal. The fatigue crack progressed in a spiral direction outward from the hole, until the forward progressing crack split and progressed circumferentially. When the

remaining cross section of the crankshaft journal could not sustain the stress due to the size of the crack, the part succumbed to overstress and fractured into two pieces.

The chemical composition of the crankshaft was inspected using energy dispersive x-ray spectroscopy (EDS) and x-ray fluorescence (XRF). The composition was consistent with type 4340 alloy steel.

A section of the crankshaft surface was mounted, polished, and etched for metallographic examination (see Figure 15). The microstructure was consistent with that of tempered martensite, the typical microstructure for this alloy steel (Figure 16a). The etching process produced a darker hue towards the surface, consistent with higher interstitial content from a case hardening surface treatment (Figure 16b).

The surface hardness of the crankshaft was inspected using microindentation hardness per ASTM E384.² The hardness data were plotted against distance from the surface in Figure 17. The hardness peaked over 50 HRC approaching the surface, before leveling off to an average of 34 HRC approximately 0.025 inches below the surface. These hardness data were consistent with a case-hardened layer, which was consistent with the observed microstructure of the surface in Figure 15. The core hardness of 34 HRC was typical for this alloy and microstructure. Surface hardness measurements from a case hardening (such as nitriding or carburizing) typically exceed 60 HRC.

Figure 18 shows the inner surface of the thrust bearings, as received. These bearing surfaces showed wear significant enough for material to spall off the inner surface. The inner surfaces also exhibited material smearing in circumferential directions, most apparent at the bearing edges. Circumferential wear marks were also evident on the outer surfaces of the bearings, but no severe material loss such as spalling was present (Figure 19).

Of note in mating the two bearing halves was apparent mismatch in size (see Figure 20). As shown in Figure 20, the three smaller holes and the one large hole did not line up seamlessly. These surfaces also exhibited distortion and indications consistent with deformation.

Figure 21 shows the three flange fragments, as received. Each of the flanges exhibited features consistent with overstress fracture along one of the edges, as well as circumferential wear marks. On one of the flanges, this wear was severe enough to leave a thin wedge of material that had undulated and folded in on itself, exposing an underlying metallic filament (Figure 22). Another flange had been deformed severely enough to curl, as exemplified on the edge illustrated in Figure 23.

Figure 24 shows the submitted connecting rod assembly, as received. The connecting rod, cap, and two bolts were intact with no apparent damage or deformation.

² ASTM E384 – *Standard Test Method for Knoop and Vickers Hardness of Materials*. ASTM International, West Conshohocken, PA

The markings on the web of the connecting rod stated "AEL11488E." The markings on the opposite web were a circled "K" and "1".

The bearings for the connecting rod and the cap, however, did exhibit damage. As shown in Figure 25, the cap bearing surface exhibited indications of gouging and material spalling. The gouging was circumferential in orientation, consistent with wear from loose material abrading the surface during rotation. These wear patterns were not mirrored on the #1 crankshaft rod journal.

Erik M Mueller
Materials Research Engineer



Figure 1 – The components from the engine, as received.

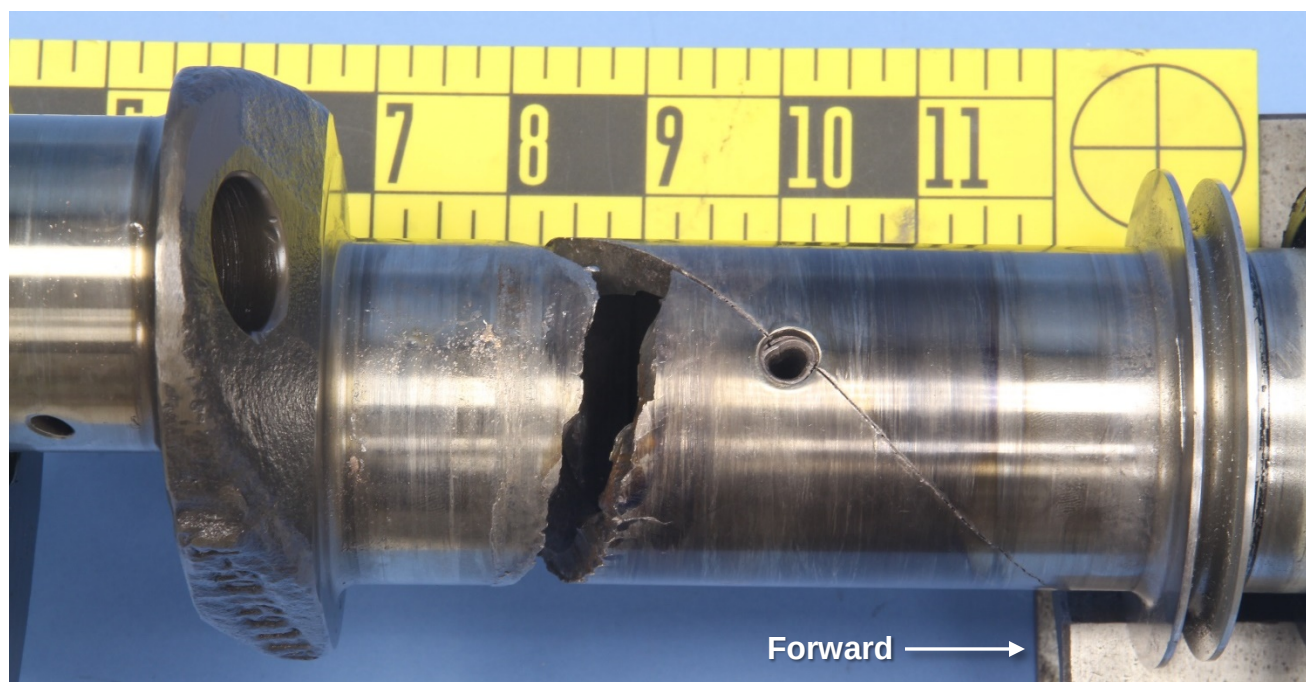


Figure 2 – View of the fractured portion of the crankshaft main journal, showing cracking across a lubrication hole, just forward of the circumferential fracture.



Figure 3 – View of the fractured portion of the crankshaft main journal, rotated 90° from Figure 2.

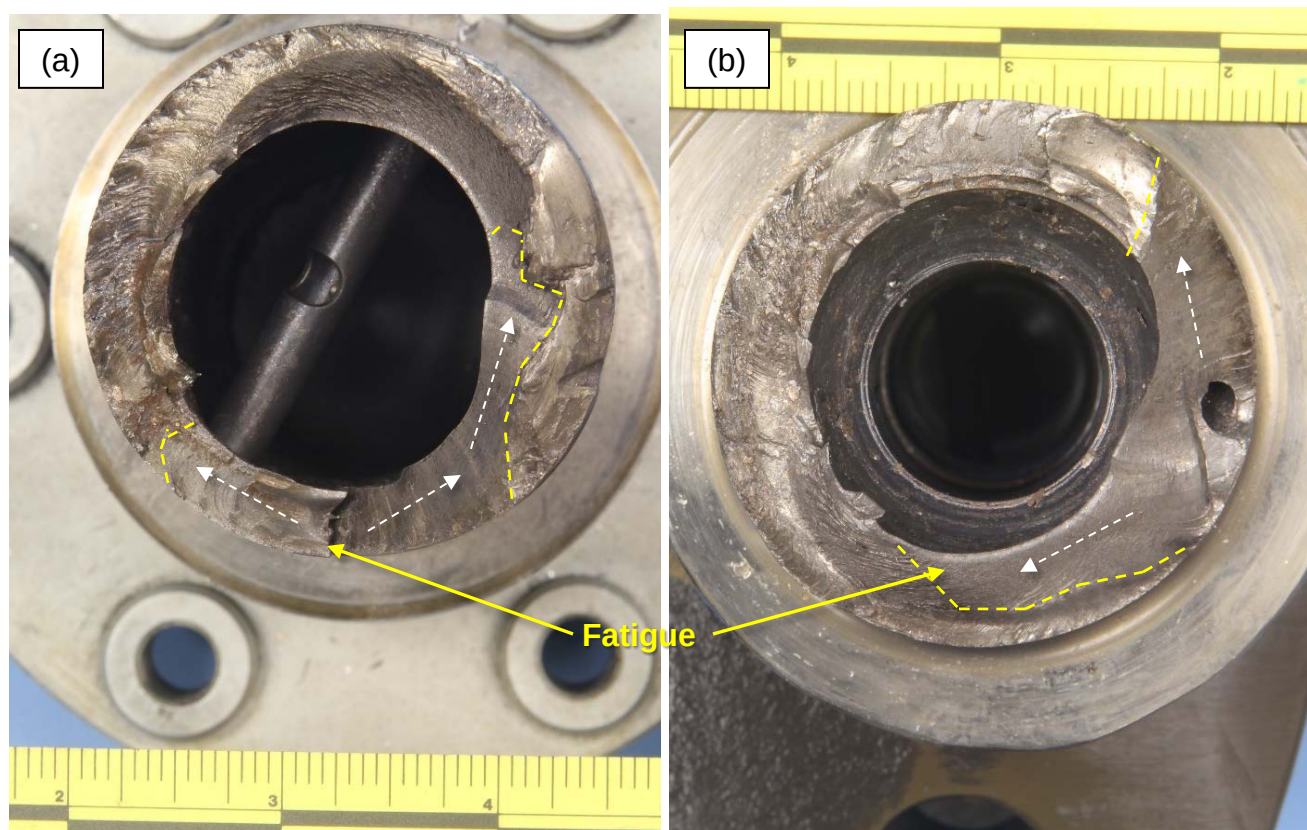


Figure 4 – View of the circumferential portion of the fracture surface on the crankshaft main journal, viewed from (a) the forward and (b) the aft faces.

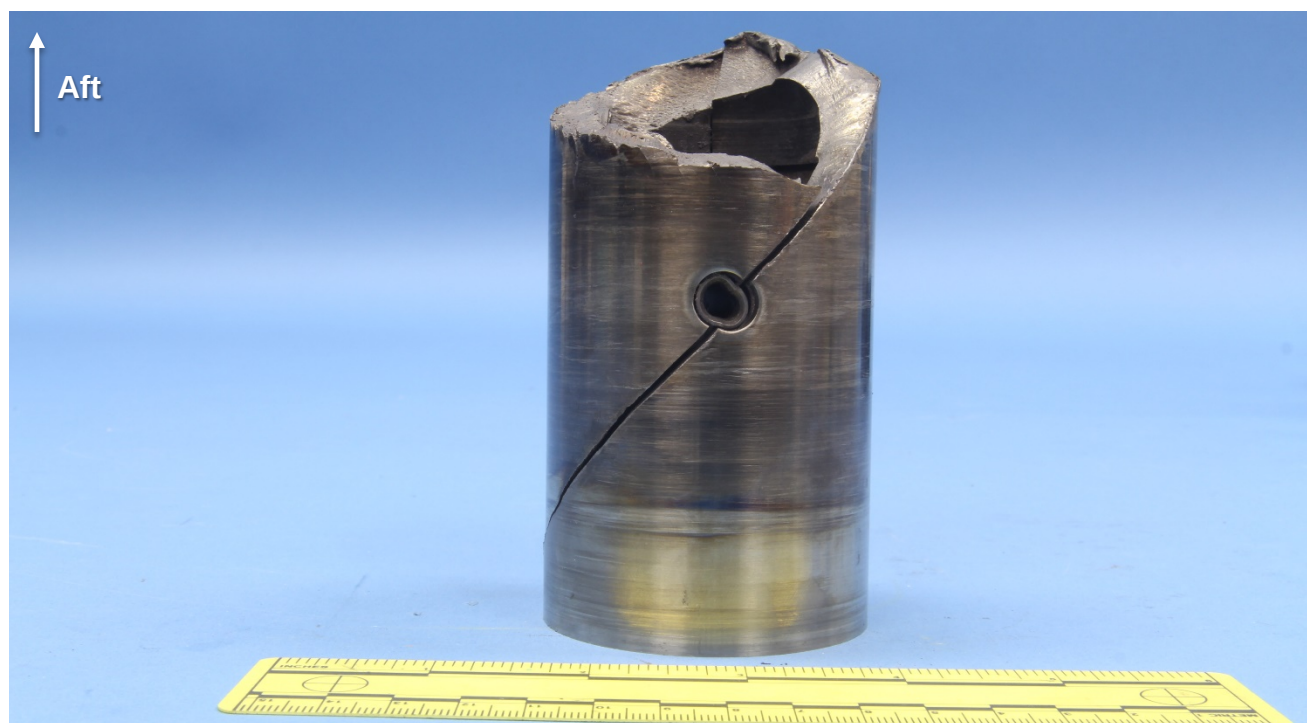


Figure 5 – The forward portion of the crankshaft main journal, after sectioning.



Figure 6 – The crankshaft journal in Figure 5, after opening to expose the spiral fracture. The sludge tube is on the bottom section, with a small cut artifact from the crankshaft sectioning.



Figure 7 – The fracture surface from the upper section in Figure 6, showing crack arrest marks emanating from the lubrication hole. Dashed white arrows depict the crack propagation direction from the oil hole.



Figure 8 – The fracture surface from the lower section in Figure 6, showing crack arrest marks emanating from the lubrication hole, which still had the oil tube in place.



Figure 9 – The sectioned and cleaned portion of the journal fracture surface in Figure 8.



Figure 10 – The crack initiation sites of the main journal fracture at the lubrication hole in Figure 9. The two arrows depict the fatigue crack initiation sites.

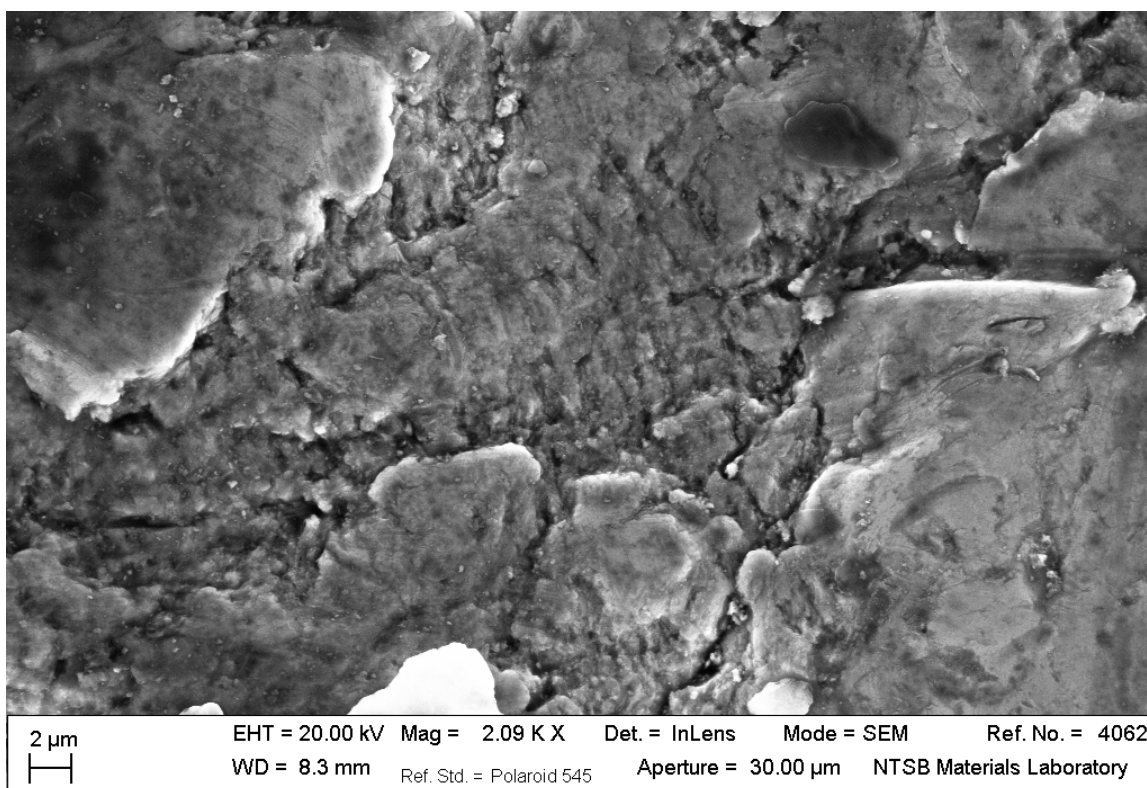


Figure 11 – Secondary electron (SE) micrograph of fatigue striations on the journal fracture surface.

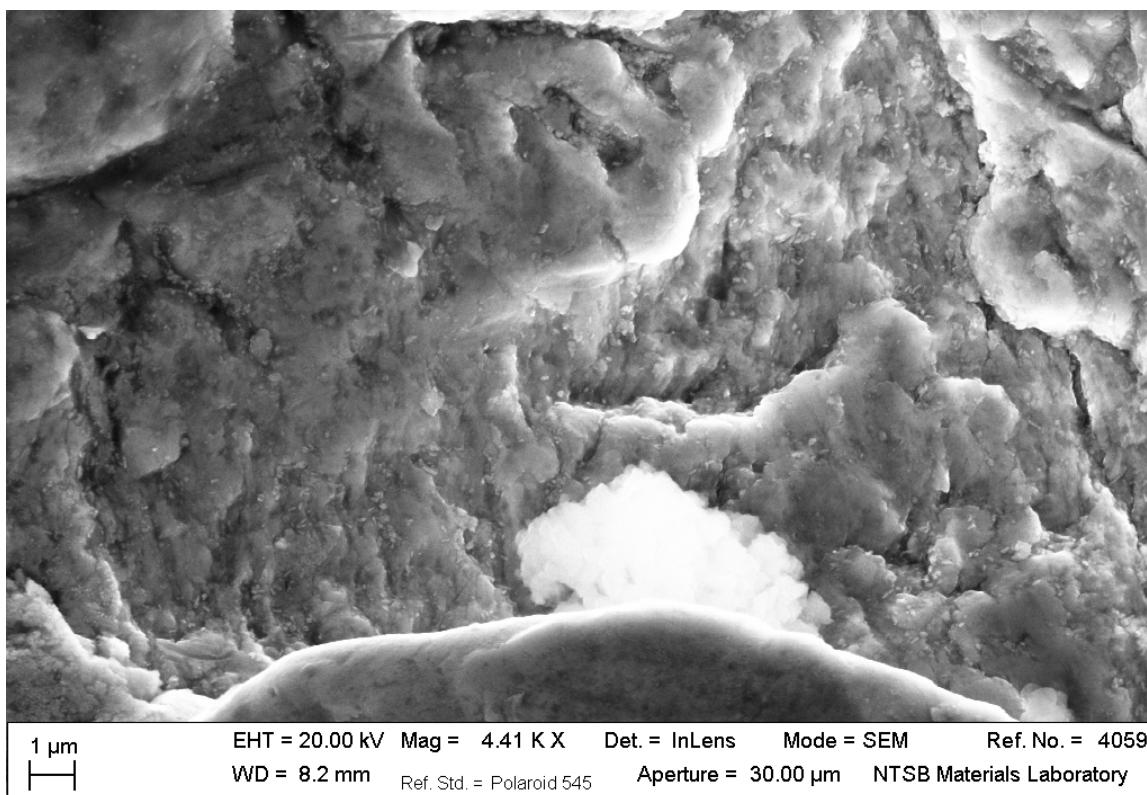


Figure 12 – SE micrograph of fatigue striations on the journal fracture surface.

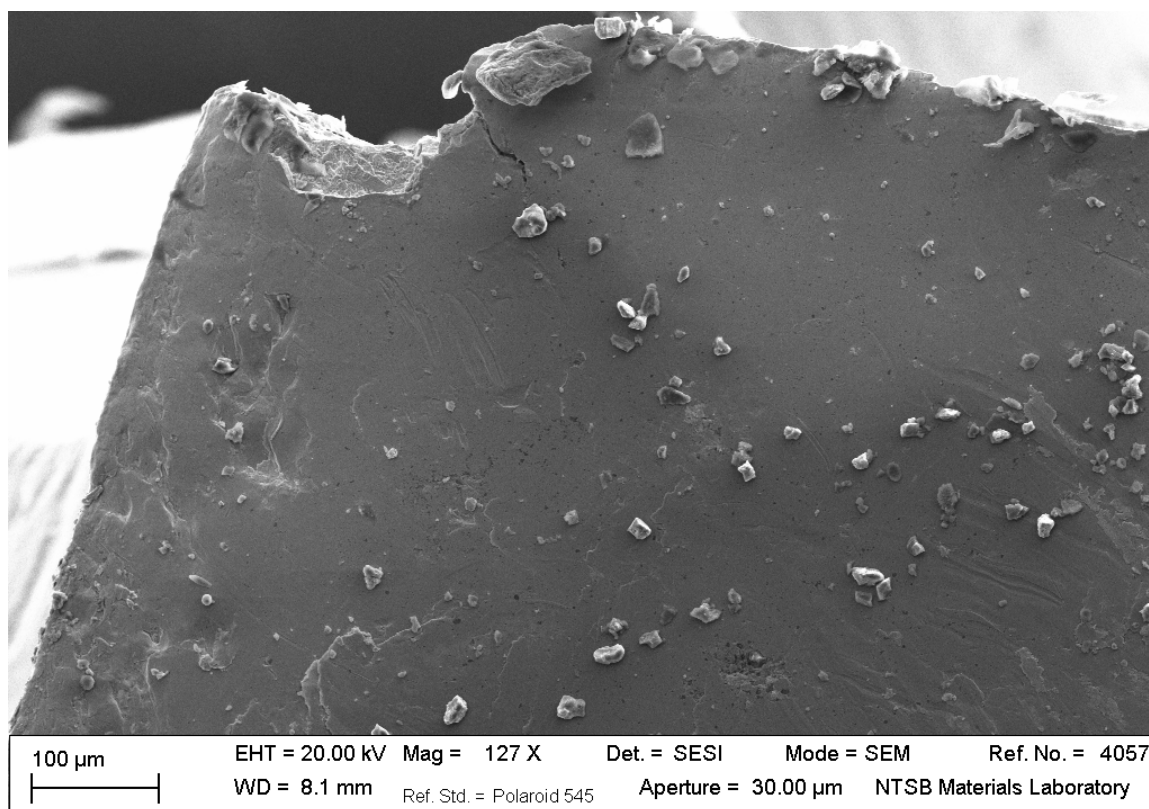


Figure 13 – SE micrograph of one of the crack initiation sites of spiral fracture.

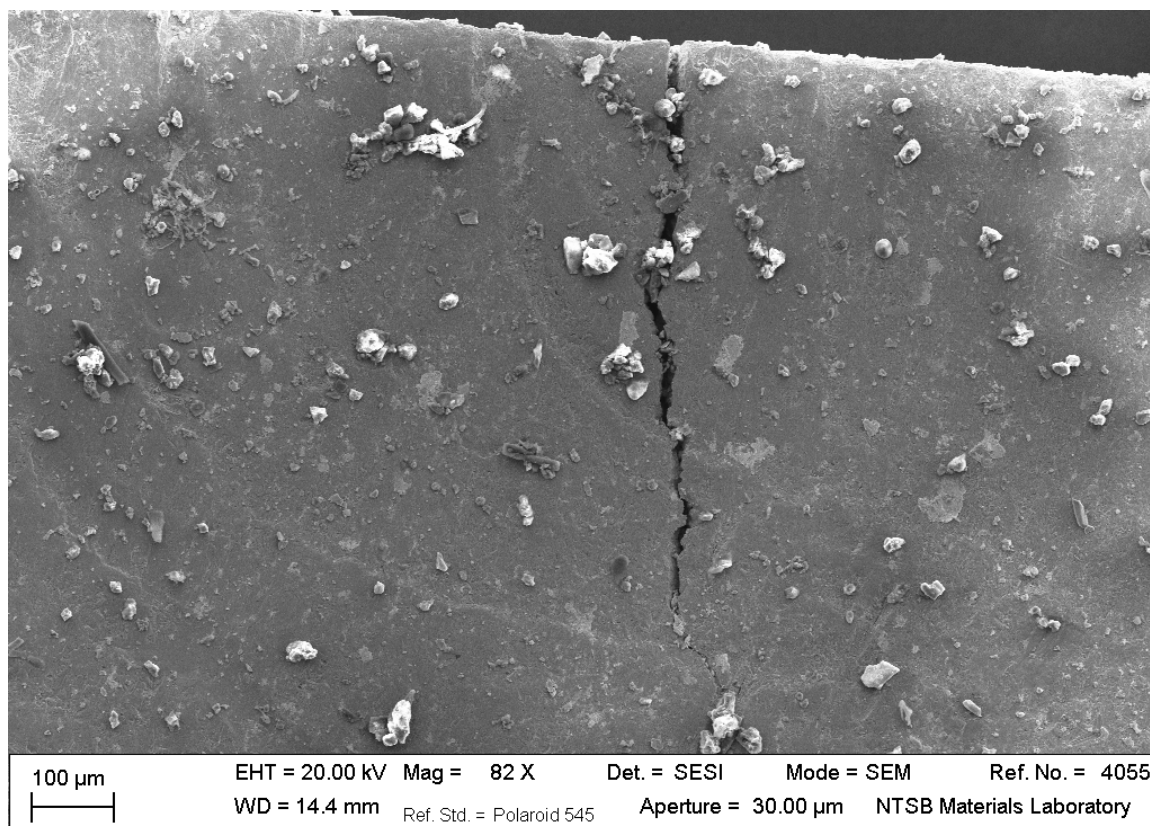


Figure 14 – SE micrograph of additional cracks in the lubrication hole.



Figure 15 – Bright-field (BF) optical micrograph of the crankshaft main journal surface (~100X, etched 2% Nital).

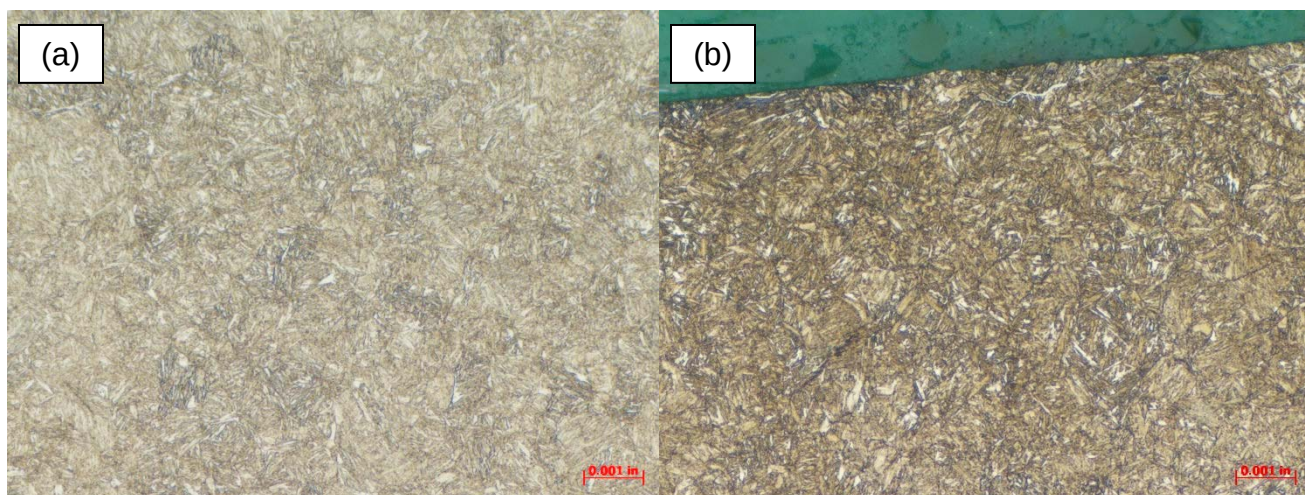


Figure 16 – BF optical micrographs of the crankshaft main journal microstructure from (a) the core and (b) near the surface (~200X, etched 2% Nital).

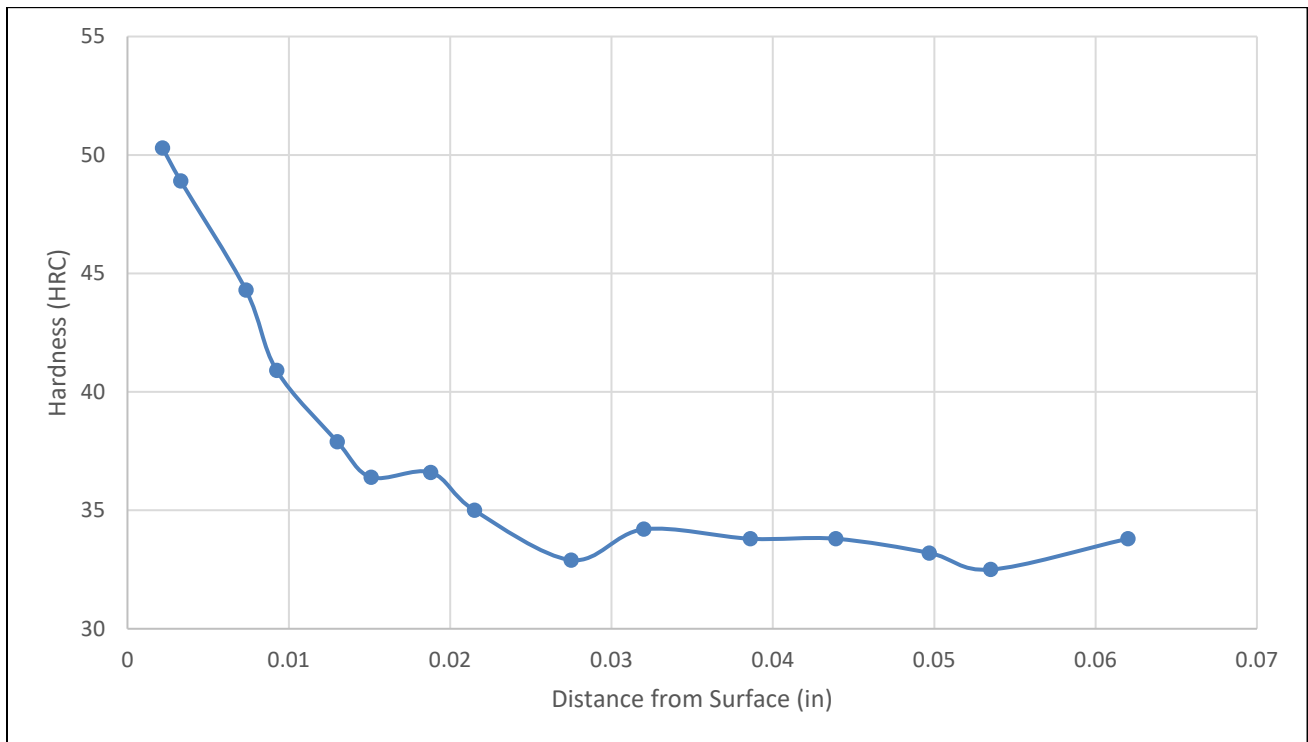


Figure 17 – Hardness (in HRC) of a cross section of the crankshaft, showing higher hardness values in the 0.020 inches closest to the surface.



Figure 18 – The main journal bearings, viewed from the inside bearing surface which exhibited wear and material spalling.



Figure 19 – View of the outer surface of the main journal bearings, showing circumferential wear marks.

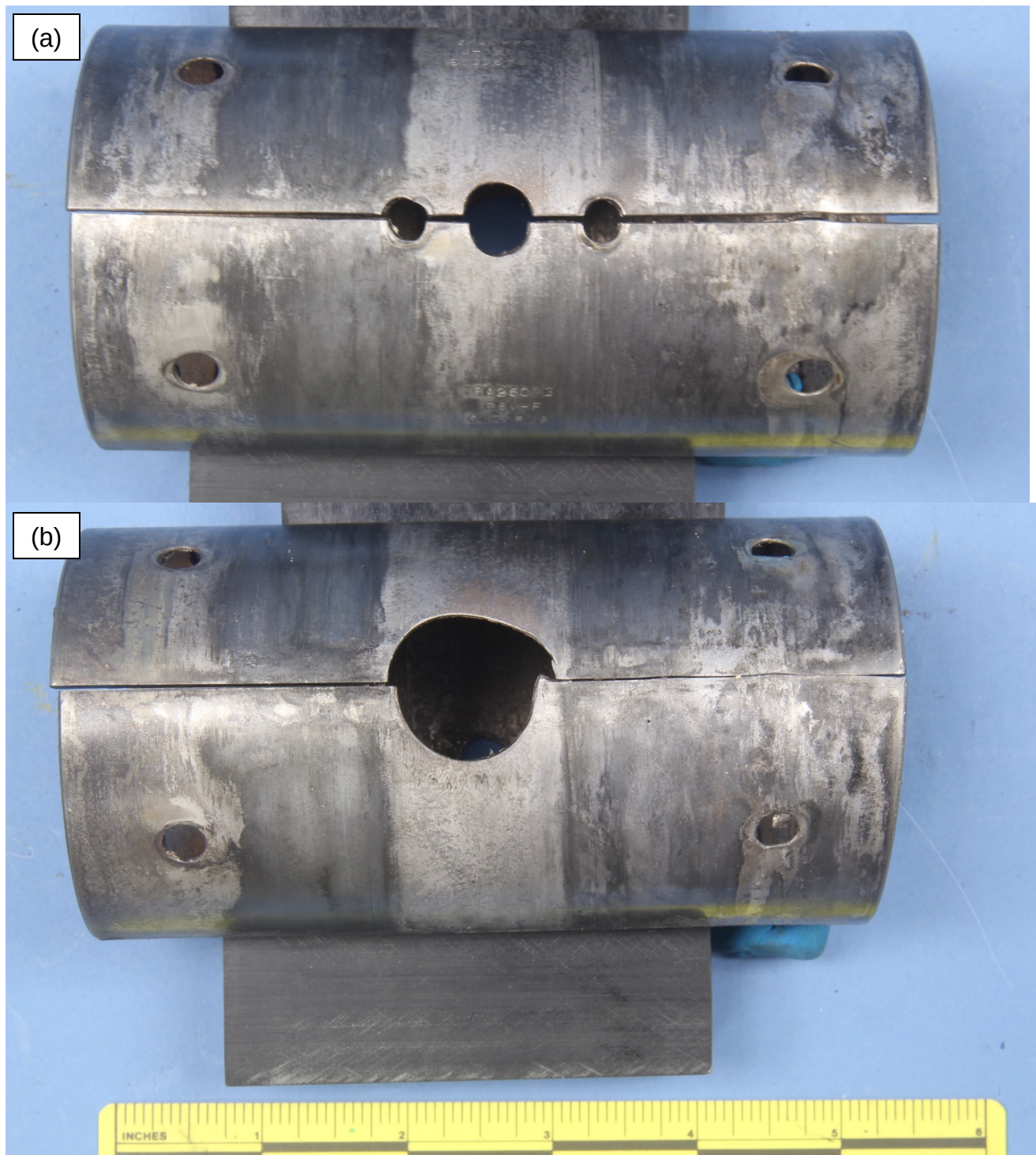


Figure 20 – The outer surfaces of the main journal bearings, mated to show minor deformation and material smearing.



Figure 21 – The three flange pieces, as received.



Figure 22 – Damage on the edge of one of the flanges.



Figure 23 – Deformation on one of the flanges severe enough to curl over on an edge.

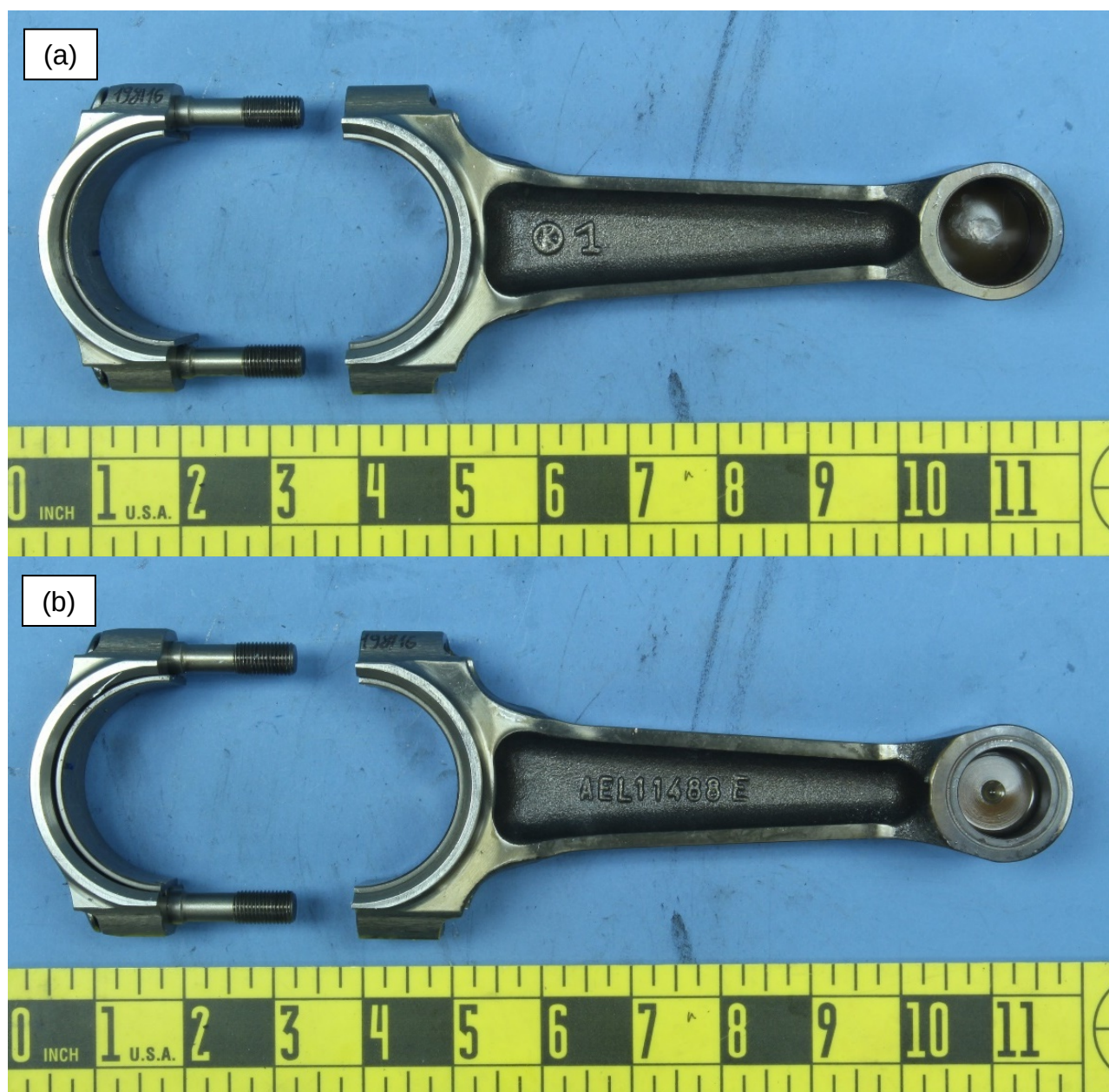


Figure 24 – The #1 connecting rod and cap viewed from (a) the obverse side and (b) the reverse side.



Figure 25 – The inner bearing surface of the connecting rod cap, showing scrape marks and material spalling.