NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

March 19, 2015

MATERIALS LABORATORY FACTUAL REPORT Report No. 15-013

1. ACCIDENT

Place : Clayton, AL
Date : April 3, 2014
Vehicle : Cessna T210L, N1631X
NTSB No. : ERA14LA179
Investigator : Heidi Moats, AS-ERA

2. COMPONENTS EXAMINED

Engine crankshaft pieces
Pieces of piston connecting rods
Engine case halves
Main bearing pieces

3. DETAILS OF THE EXAMINATION

On April 3, 2014 about 1530 central daylight time, a Cessna T210L was substantially damaged during a forced landing to a road following a total loss of engine power near Clayton, Alabama. According to the flight instructor, the engine fuel flow was lower than expected during the flight. Initial examination of the airplane by a Federal Aviation Administration inspector revealed that the engine firewall was crushed aft, and that both wings were substantially damaged. The airplane's engine, a Teledyne Continental (TCM) TSIO-520-R, and a portable GPS unit were retained by the NTSB for further examination.[1] According to the IIC, three of the engine cylinders were changed in January 2014.

Figure 1 illustrates the fractured crankshaft, piston rods, and bearing pieces, as received. The engine analyzer module in Figure 1 was submitted to the NTSB Vehicle Recorder Division for further investigation.[2] The crankshaft had fractured at a web just forward of the #2 connecting rod journal and aft of the #2 main rod journal, as shown in Figure 2.[3] The mating fracture surfaces of the web are illustrated in Figure 3. The aft fracture surface was battered such that most fracture features were obliterated, consistent with post-fracture damage (see Figure 4). The mating forward face was relatively unsullied, and exhibited crack arrest marks along the surface, as illustrated in Figure 5. These

[1] The TSIO-520 is a six cylinder, horizontally opposed, turbo-charged fuel injection piston engine produced by TCM.
[2] See NTSB *Vehicle Recorder Specialist Factual Report.*
[3] TCM crankshafts journals are numbered from the rear of the engine to the forward. Main and cylinder journals are numbered independently.

features were consistent with progressive cracking. The forwardmost portion of the fracture (the initial stages of the crack propagation) exhibited small ratchet marks indicative of multiple crack initiation sites.

The adjacent crankshaft journal exhibited circumferential wear scars (see Figure 3). The journal surface closest to the aft fracture surface exhibited color changes that ranged from yellow and orange to purple and dark blue, moving aft to forward along the journal surface toward the fracture surface (see Figure 3 and Figure 4).

The web fracture was examined using a scanning electron microscope. As shown in Figure 6, the fracture surface exhibited fatigue striations consistent with fatigue crack propagation. The crack initiation sites are displayed in Figure 7. The initiation sites were smooth, with no indications of material defects such as inclusions, pits, or voids. There were no machine marks in these areas or along the journal fillet shown to have initiated cracks.

Along the bearing journal surface just forward of the fatigue crack initiation sites, there were material deposits associated with galling wear (Figure 8). The chemical composition of this material was inspected using energy dispersive x-ray spectroscopy (EDS). This galled material was consistent with babbitt material typical of bearing materials using in airplane piston engines. In contrast, the material of the bearing journal and crankshaft were consistent with alloy steel.

Figure 9 shows the left half (aft looking forward) of the engine case with the fractured crankshaft placed in its working position. The fracture in the crankshaft web corresponded with the location of the #1 cylinder. The interior surfaces of both case halves exhibited smearing and impact damage consistent with the location of the crankshaft fracture (see Figure 10). The aftmost main bearing journal of the case exhibited outward plastic deformation along the edges. In addition, the bearing surface exhibited circumferential material spalling (see Figure 10a).

The remnants of the babbitt material are illustrated in Figure 11. These components, which were comprised of layers of multiple materials, had been crushed and mixed together. Two of these crushed components exhibited a rounded lip, consistent with the aft bearing edge smeared on the second main bearing in Figure 10a.

Figure 12 shows the #2 connecting rod, as received. This connecting rod exhibited the most damage of the two submitted—the aft side faces of the cap and rod yoke exhibited smearing and impact damage. The bearing surfaces of the rod and cap exhibited circumferential wear scars and indications of material spalling. The bearing material near the bolt holes exhibited smearing.

One of the bolts for the #2 connecting rod cap was intact, but bent outboard; the other bolt had fractured (see Figure 13 and Figure 15, respectively). The fractured bolts exhibited a fracture surface with a 45° slant and local plastic deformation. Figure 16 illustrates the fracture surface of the bolt. The fracture exhibited a dull gray luster, with a rough surface and radial patterns consistent with a fracture direction from left to right in the figure. Examination using a scanning electron microscope found the fracture surface to exhibit dimple rupture (Figure 17). These fracture features were consistent with failure by tensile overstress.

Figure 18 illustrates the #6 connecting rod and cap, as received. These components were in relatively good condition, and they exhibited no indications of macroscopic damage or deformation. Both bolts for the rod cap were intact with no indications of deformation or thread wear.

The bearing surfaces of the rod and cap exhibited circumferential wear marks consistent with wear from the adjacent crankshaft bearing surfaces. Approximately half of the rod bearing surfaces exhibited dark discoloration that was generally uneven (see Figure 19).

The babbitt bearing material corresponding with this rod position is shown in Figure 20. Most of these components were generally intact, as opposed to the #2 components. However, these bearings exhibited heavy circumferential wear scars, spalling, galling, and radial deformation. The corresponding crankshaft journal exhibited circumferential wear scars, with surface darkening and heat tinting. These features were consistent with elevated temperature exposure and oil degradation.

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Materials Research Engineer

Figure 1 – The engine components, excluding the engine case halves, as received.

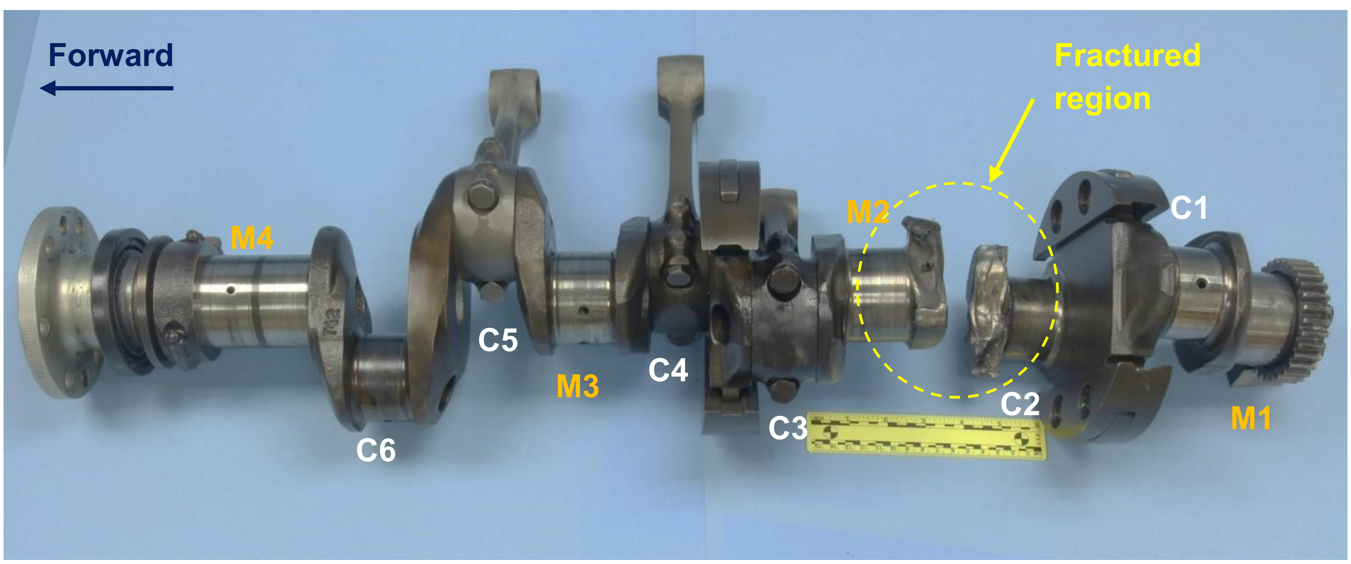

Figure 2 – Both halves of the crankshaft as received. The main journals are labeled “M1” through “M4” in orange text. The connecting rod journals are labeled “C1” through “C6” in white text, right to left.

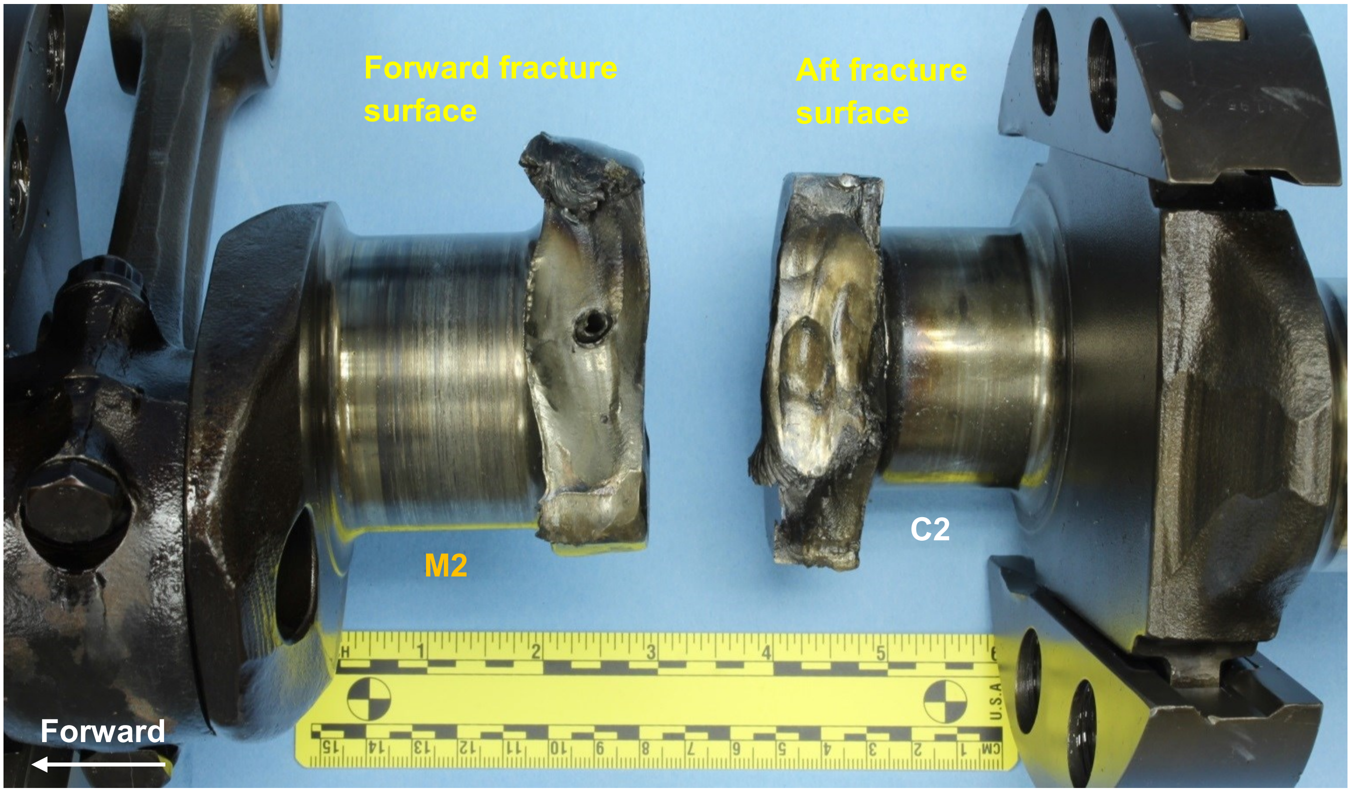

Figure 3 – The mating fracture surfaces of the crankshaft, as received.

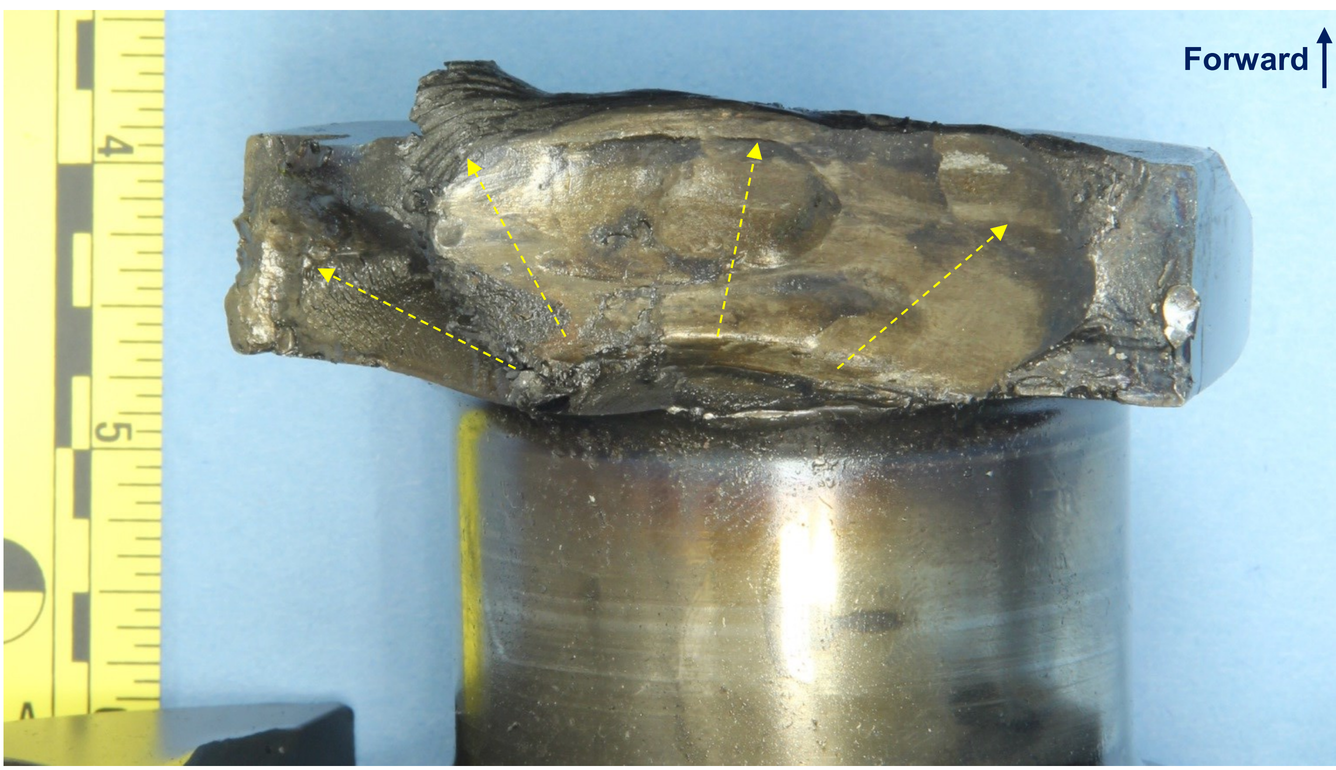

Figure 4 – The aft fracture surface of the web, as received. The surface exhibited batter consistent with post-fracture damage. The dashed lines represent the crack propagation direction.

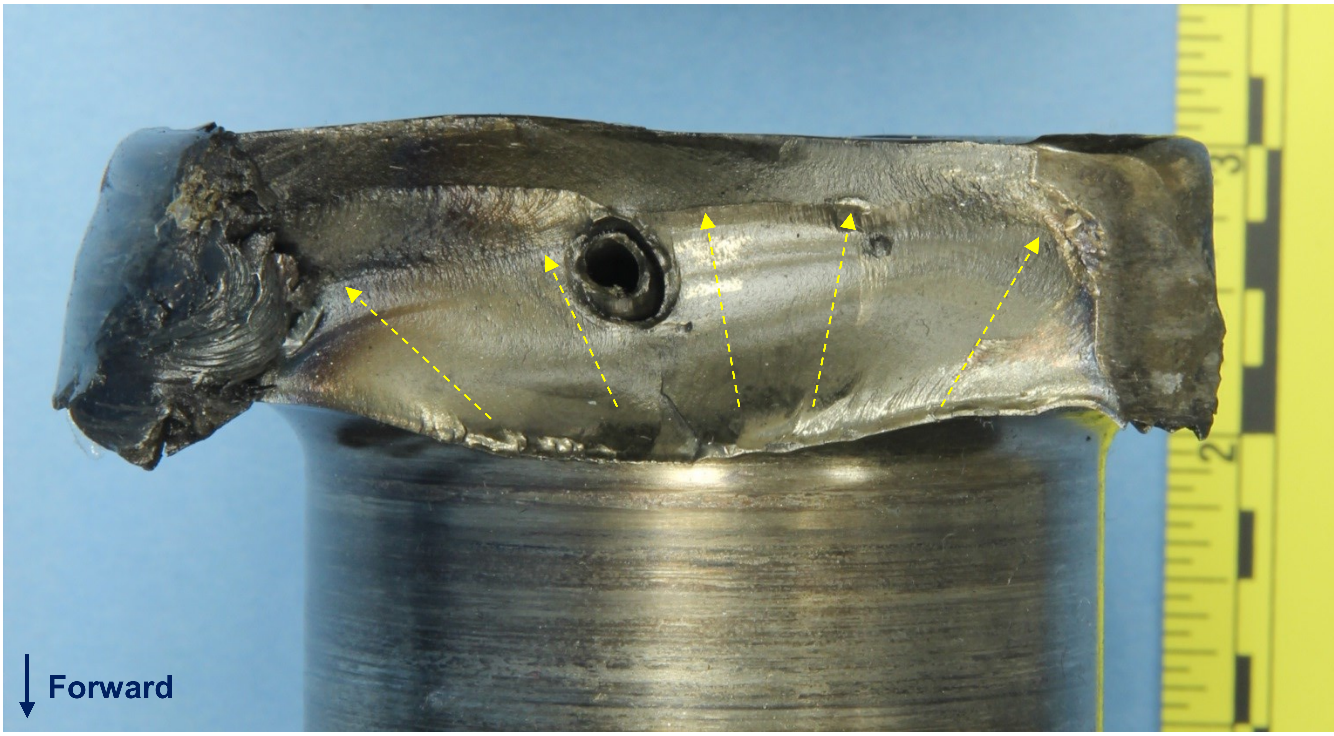

Figure 5 – The forward fracture surface of the web, as received. The fracture surface exhibited crack arrest marks and ratchet marks. The dashed lines represent the crack propagation direction.

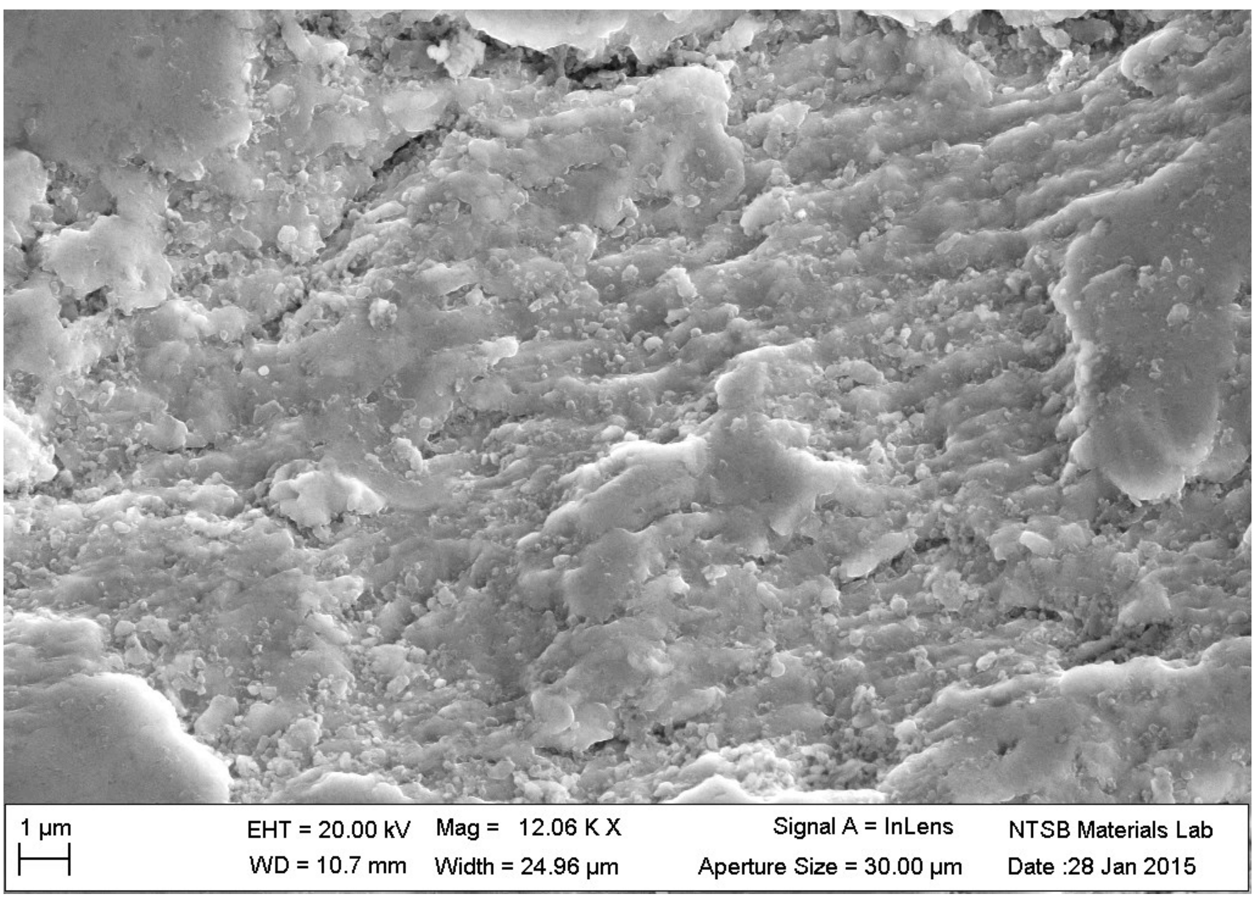

Figure 6 – Secondary electron (SE) micrograph of fatigue striations on the web forward fracture surface.

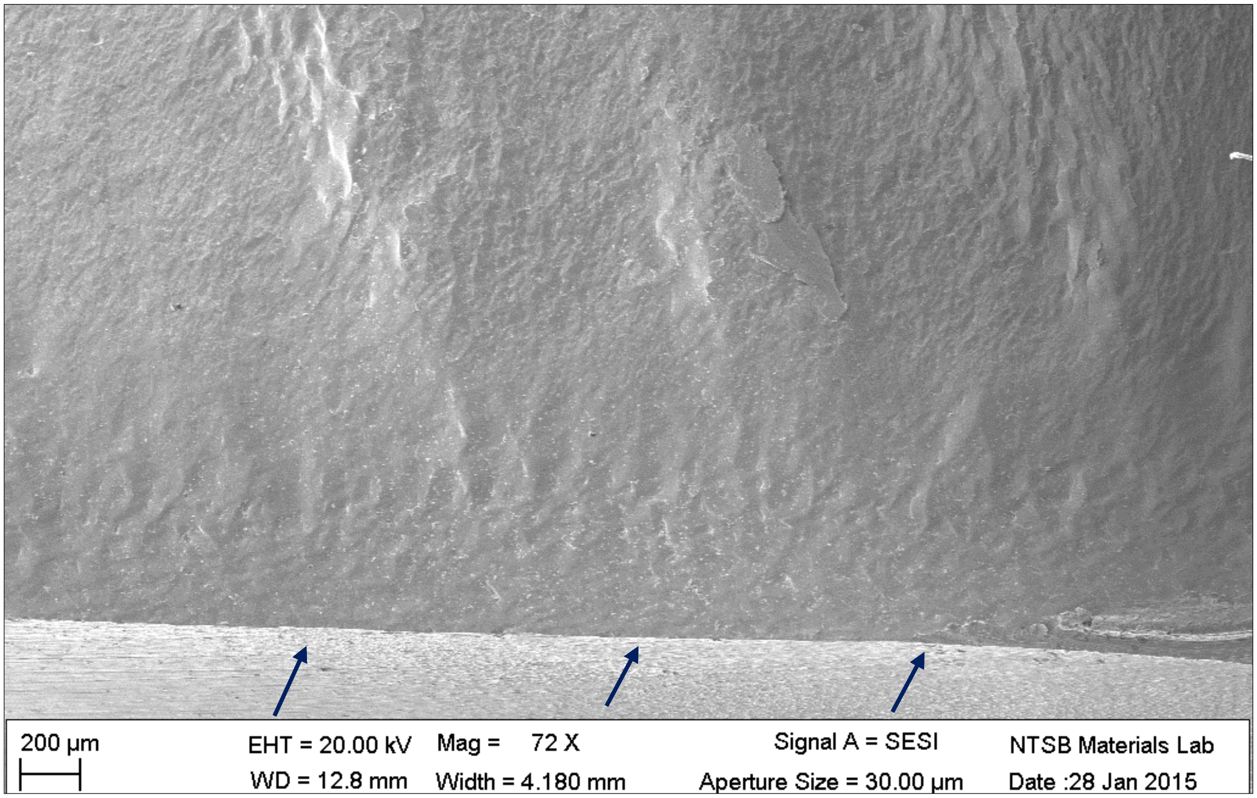

Figure 7 – SE micrograph of the fatigue crack initiation site on the web forward fracture surface (arrow).

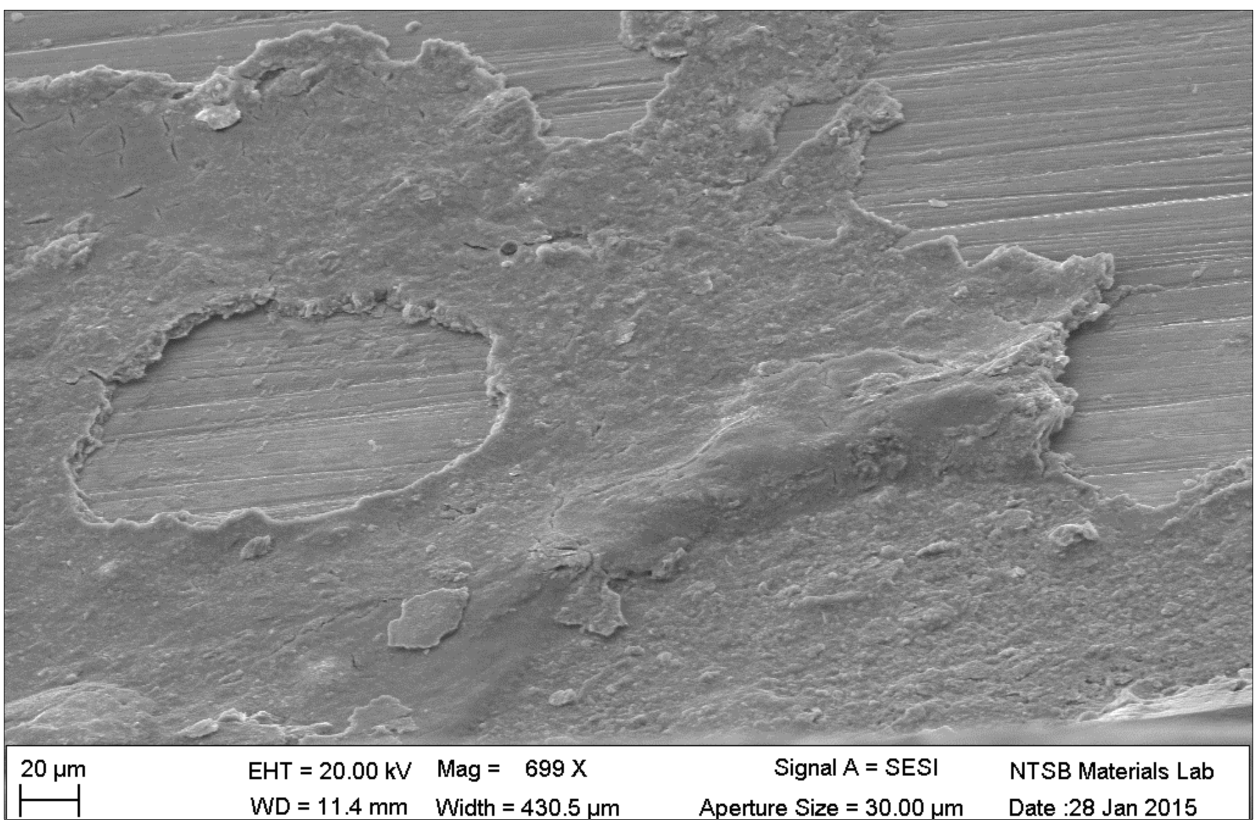

Figure 8 – SE micrograph of galled material deposits on the bearing journal aft of the web forward fracture initiation point.

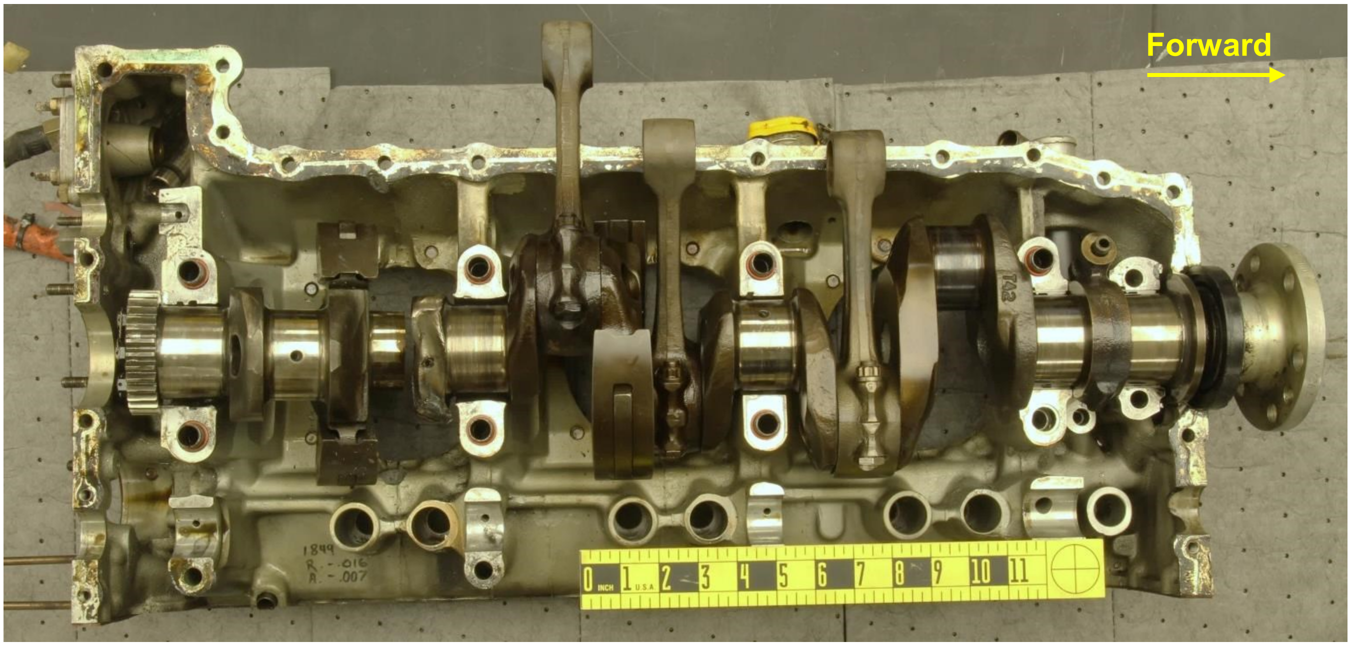

Figure 9 – The left half of the engine case, with the crankshaft placed in its previous location.

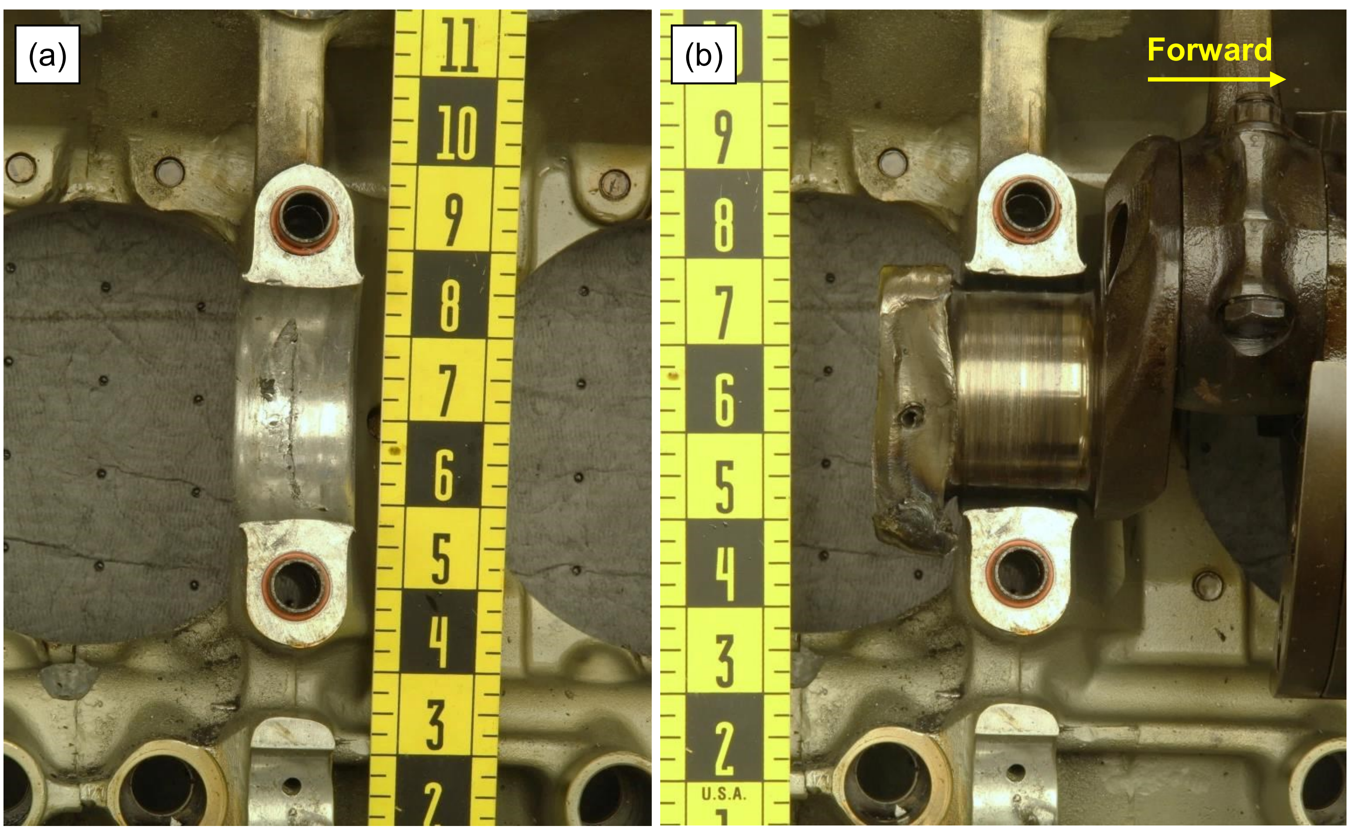

Figure 10 – The second main bearing journal of the left case (a) without the crankcase and (b) with the crankcase in position.

Figure 11 – Bearing pieces from the main bearing position in Figure 10, after cleaning.

Figure 12 – Portions of the #2 connecting rod and rod cap assembly, as received.

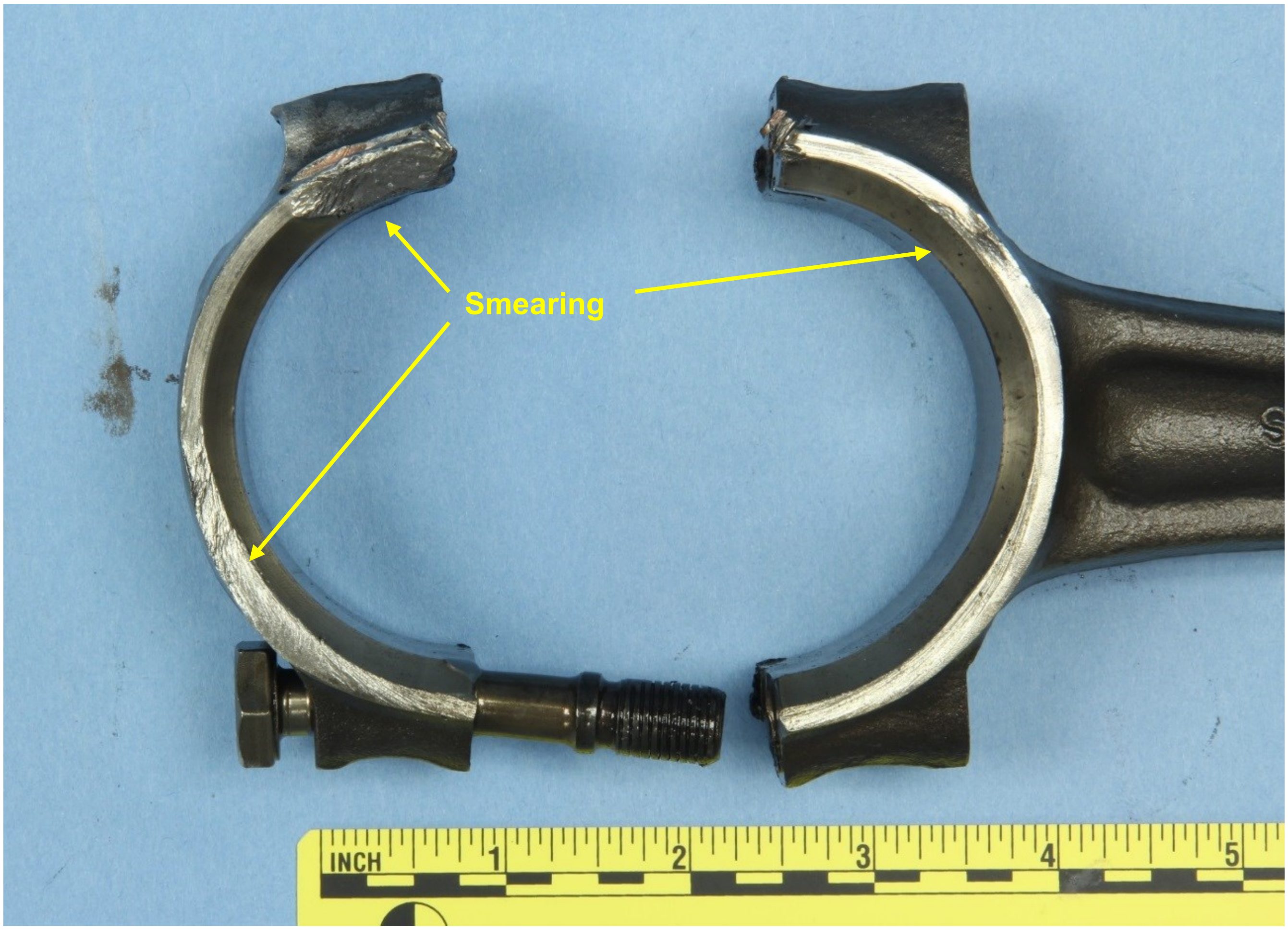

Figure 13 – The connecting rod and cap, viewed opposite of Figure 12. Smearing damage was present on the aft side flat surfaces. The rod bolt (bottom of figure) was bent outward.

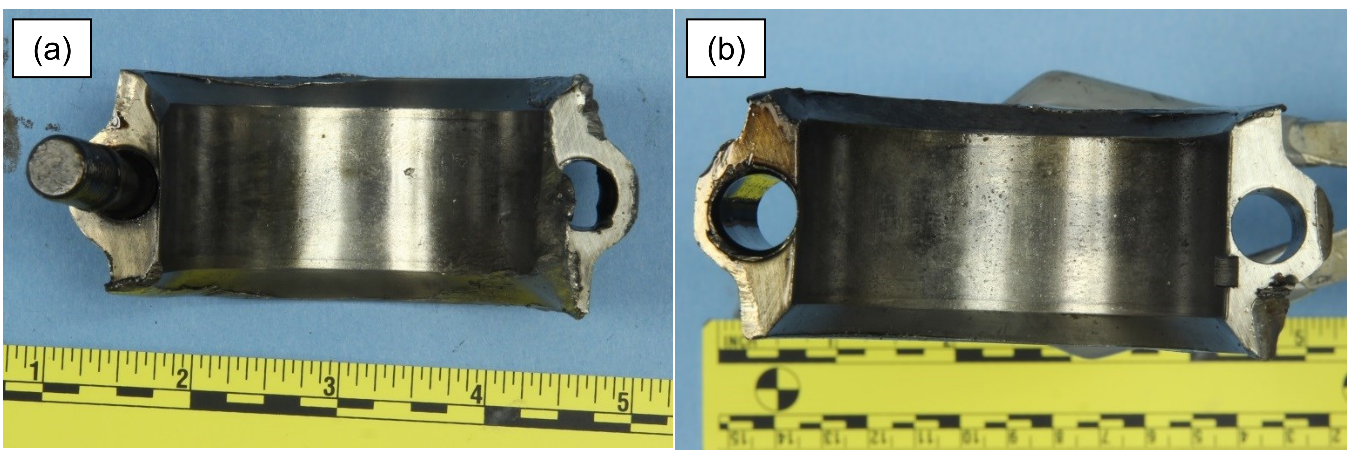

Figure 14 – The bearing surfaces of the #2 (a) connecting rod cap and (b) the connecting rod.

Figure 15 – The fractured rod bolt pieces from the #2 connecting rod. The bolt had fractured on the right.

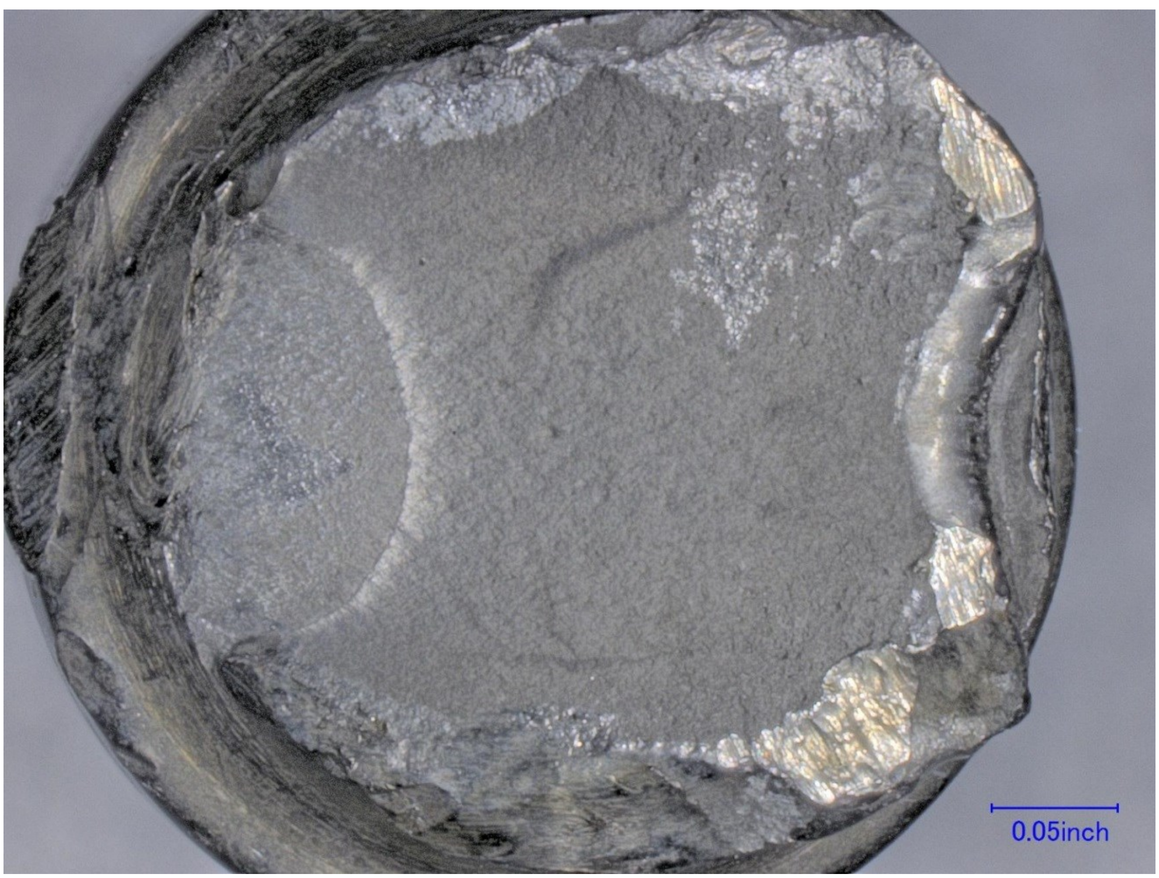

Figure 16 – The fracture surface of the broken rod bolt from the #2 connecting rod.

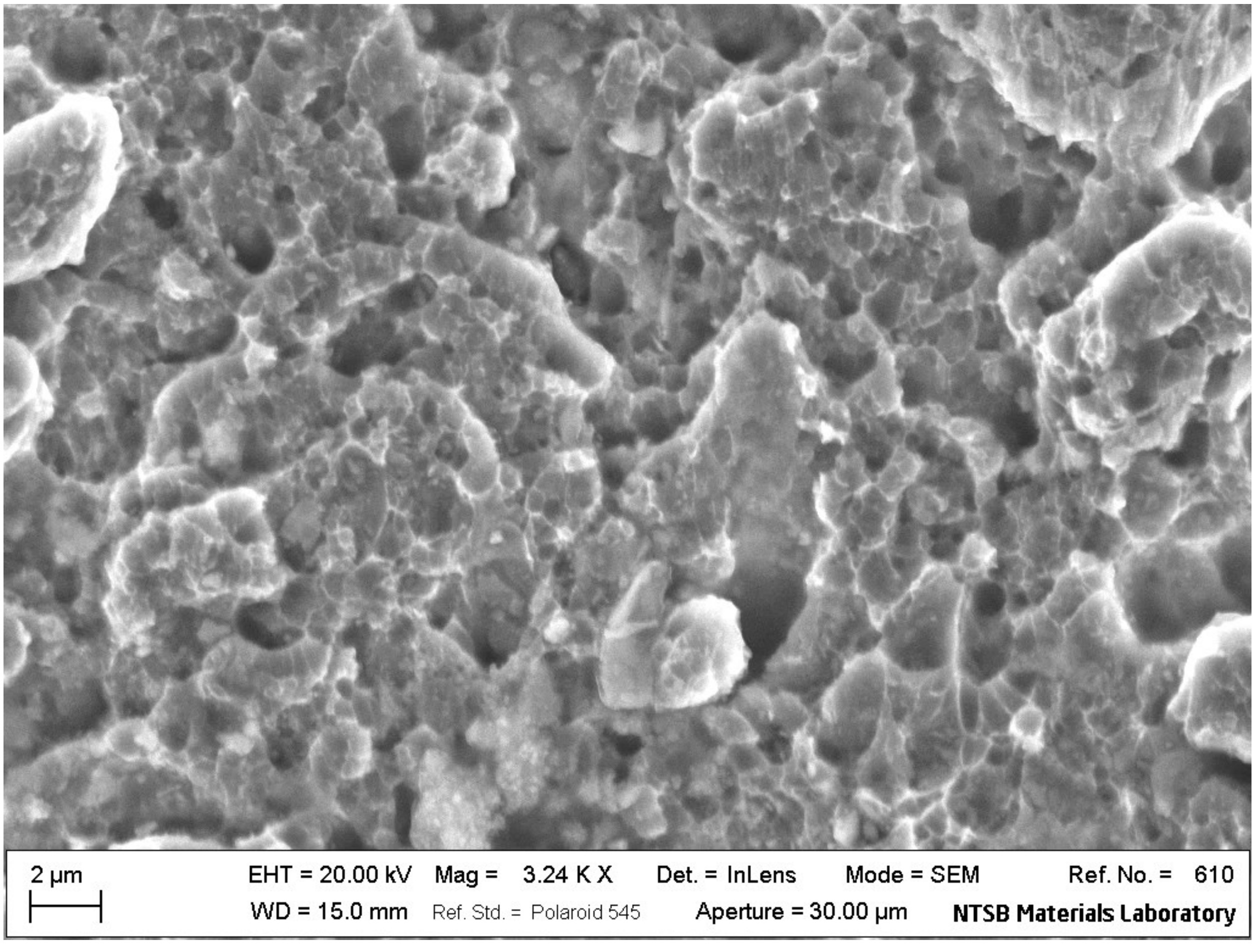

Figure 17 – SE micrograph of the fracture surface of the bolt in Figure 16, showing dimple rupture.

Figure 18 – The #6 connecting rod and cap, as received.

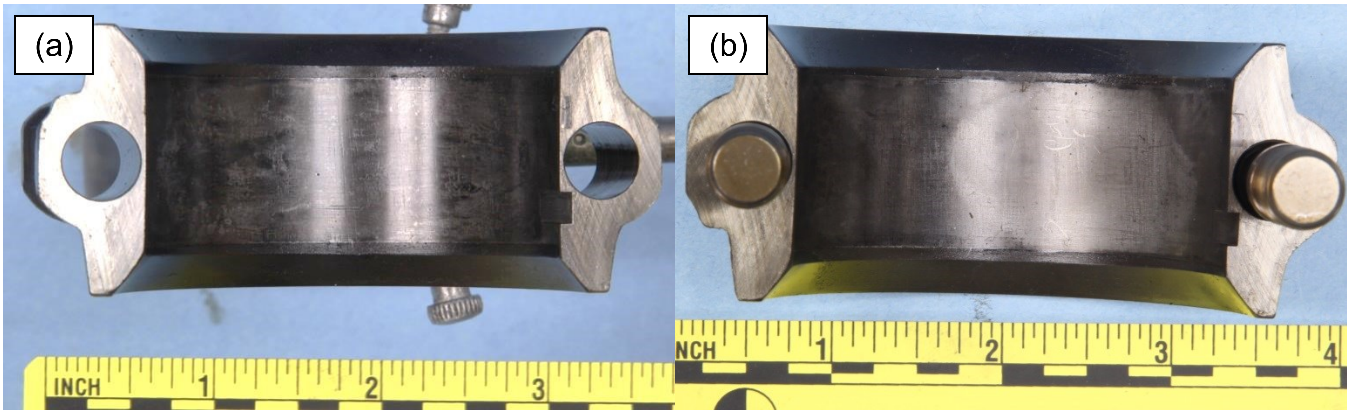

Figure 19 - The bearing surfaces of the #6 (a) connecting rod and (b) the connecting rod cap.

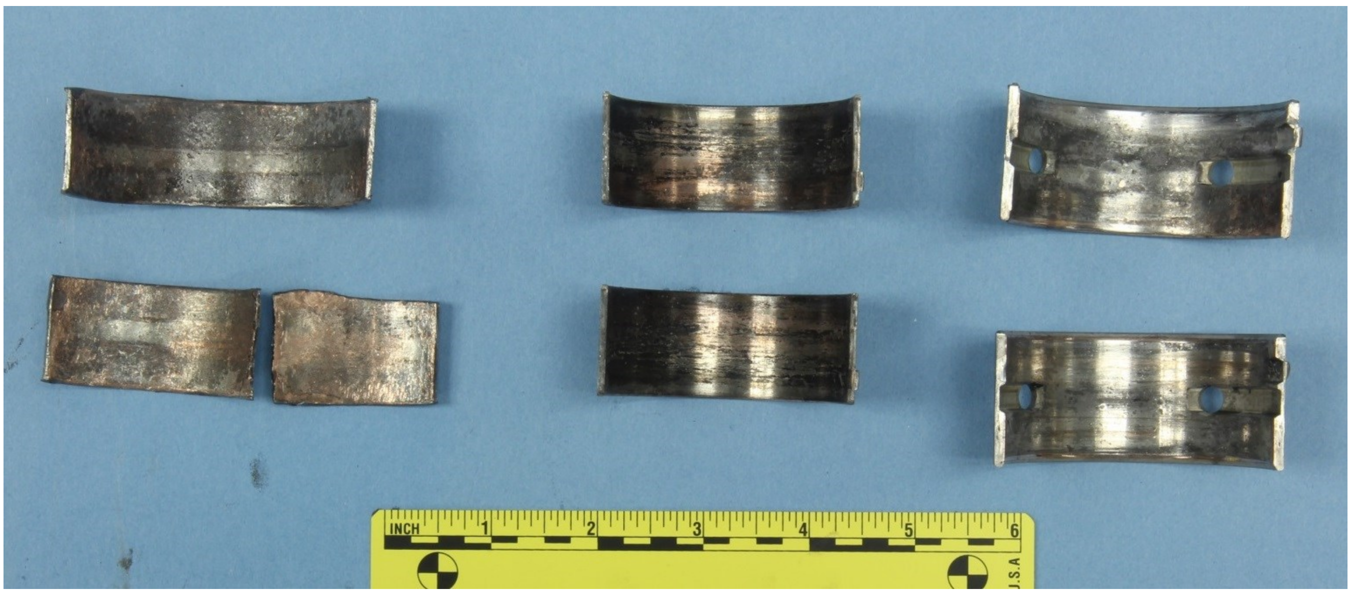

Figure 20 – The journal bearings from the #6 position after cleaning. The bearing surfaces exhibited circumferential wear scars, plastic deformation, and spalling.

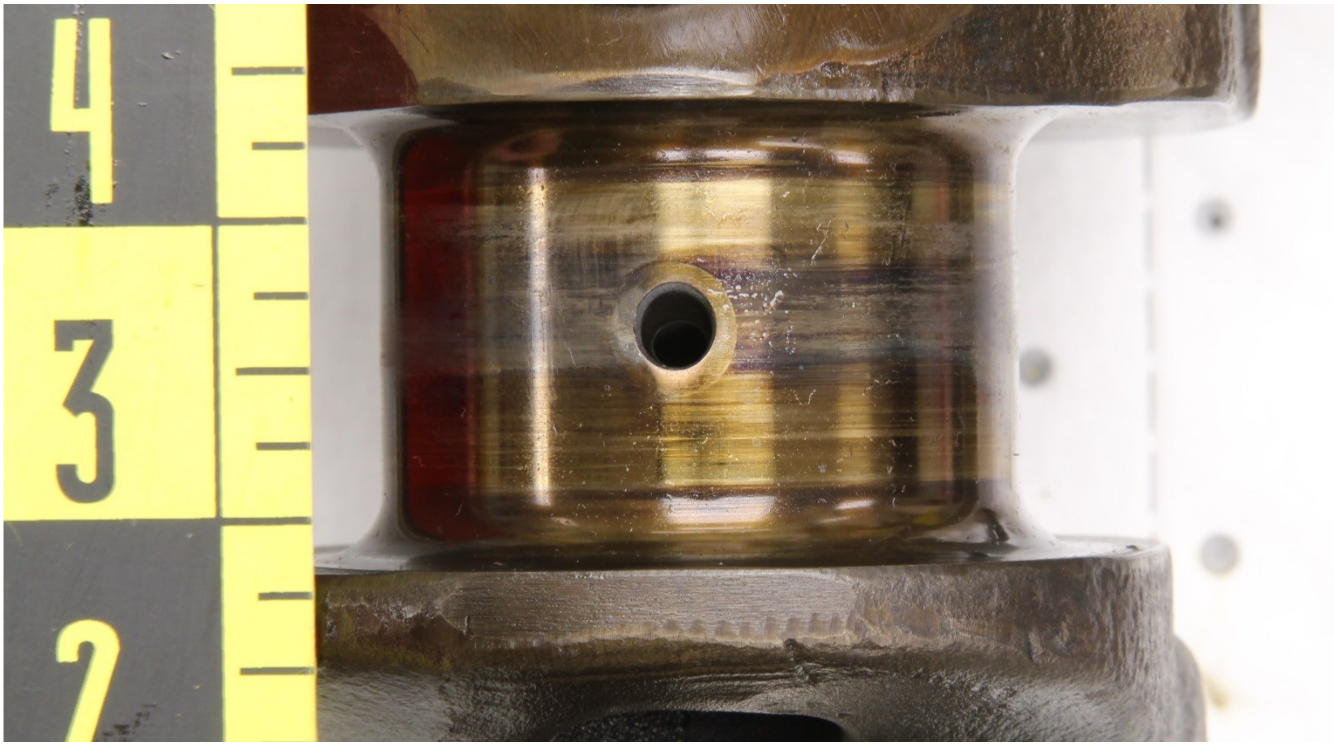

Figure 21 – The #6 bearing journal of the crankshaft, as received.