

NATIONAL TRANSPORTATION SAFETY BOARD

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

November 22, 2019



MATERIALS LABORATORY FACTUAL REPORT

Report No. 19-059

1. ACCIDENT INFORMATION

Place : Casa Grande, Arizona
Date : August 29, 2018
Vehicle : Piper PA-28-181, N4139A
NTSB No. : WPR18LA248
Investigator : Stephen Stein, AS-WPR

2. COMPONENTS EXAMINED

Remnants of #4 connecting rod
Remnants of piston, piston ring
Remnant of #4 cylinder assembly
Piston pin
Spark plugs

3. DETAILS OF THE EXAMINATION

On August 29, 2018, about 1840 mountain standard time, a Piper PA-28-181 airplane was substantially damaged during a forced landing in Casa Grande, AZ. The private pilot and pilot-rated passenger were not injured. According to the pilot, the engine started shaking violently and sputtering during flight. Neither pilot observed illumination of any annunciator lights. The pilot and pilot-rated passenger selected a road, and the airplane touched down uneventfully. Post-accident photos furnished by local law enforcement revealed the top of the engine cowl was breached, and a streak of oil was present on the windshield.

Several components from the Lycoming O-360-A1D were retained and sent to the NTSB Materials Laboratory for additional examination.¹ The engine had a total time of 1569 flight hours, with 42 hours since the most recent overhaul. Several components had been replaced during the overhaul, including the bushings, connecting rod bolts, bearings, and the connecting rods.

¹ The Lycoming O-360-A1D is a four-cylinder, direct-drive, horizontally opposed, air-cooled, piston aircraft engines, operating at 180 hp (134 kW) at 2700 rpm with a compression ratio of 8.50:1. The engine is manufactured by Lycoming Engines, headquartered in Williamsport, PA.

Figure 1 shows the remnants of the connecting rod assembly from the #4 engine position, as received. The crankshaft side of the connecting rod assembly was generally intact, with the attachment bolts and nuts submitted together. The pin side of the rod assembly had broken into multiple pieces, and the neck of the rod was bent down and backward. Three smaller fragments of the connecting rod assembly were found; these pieces were consistent with having made up the piston pin bore of the rod.

Figure 2 shows the raised markings of the connecting rod of the web of the neck. The markings state "LW-11488 TW 8-5". The raised markings on the reverse side stated, "A35 B". There were also faded stamped markings on the side of the part, which stated, "LW 11750".

Figure 3 shows the piston pin bore surface remnant on the connecting rod fragment, as received. This figure also illustrates the degree of bending in the neck of the rod. This bore face of the rod was sectioned away from the neck and is displayed in Figures 4 through 6. As shown in Figure 4, the surface facing the pin and internal bushing was heavily gouged, battered, and scraped. This damage was consistent with post-fracture impact damage with adjacent parts.

Figure 5 shows a closer view of one of the fractured sides of the pin bore. Any fracture features that may have been present were obliterated by post-fracture impact with adjacent components. Figure 6 highlights some of this damage—there was gouging in multiple directions, batter of the fractured corner, and material flow from heavy deformation of the pin bore face.

One of the of the fragments of the connecting rod pin bore walls is highlighted in Figure 7. This was the middle piece of the three small fragments in Figure 1. Figure 7 shows a relatively undamaged fracture surface. This fracture surface exhibited crack arrest marks on the entirety of the undamaged surface. The part was examined using a scanning electron microscope (SEM). As demonstrated in Figure 8, the fracture surface exhibited fatigue striations, consistent with fatigue crack propagation. These striations exhibited varied spacing, consistent with spectrum loading in high cycle applications, typical of reciprocating engines.

Figure 10 shows the initiation area of the pin bore wall remnant. As illustrated in Figure 10 and Figure 11, any of the initiation features in this corner had been obliterated by inward smearing of the part. However, the nature of the visual features and fatigue striations was consistent with propagation from the lower right corner in Figures 10 and 11. This area was consistent with the inner face of the pin bore corner of the connecting rod.

This remnant was sectioned approximately 0.25 inches away from and oriented parallel to the fatigue fracture surface. This section was mounted, polished, and etched using a 2% Nital solution.² As shown in Figures 12 and 13, the connecting rod

² Nital – A mixture of 2% concentrated nitric acid in ethanol.

microstructure exhibited a structure consistent with tempered martensite. The surface was undulating and rumped, consistent with the service use and damage experienced by the part. There were some small surface cracks, as evidenced in Figure 12. These cracks were no more than 0.002 inches deep, as observed. Figure 13 shows a white area on the surface. This area was consistent with martensite (that had not been tempered). The presence of this phase on the surface suggests this area was subject to elevated temperature (greater than 1340 °F / 727 °C) and then rapidly cooled. This process is common in steels under rapid and localized friction forces.

The part chemistry was inspected using energy dispersive x-ray spectroscopy (EDS) and x-ray fluorescence (XRF). The connecting rod composition was consistent with an alloy steel. The tempered martensite microstructure is common for this type of steel alloy.

The hardness of the connecting rod pin bore remnant was inspected using microindentation hardness per ASTM E384.³ The hardness for the part averaged 35 HRC (353 HK₅₀₀). These data were consistent with the alloy and microstructure observed. The data from the microindentation hardness found no significant different in hardness values between the surface and the core of the remnant.

Figures 14 and 15 show the bushing remnant that had been present in the connecting rod pin bore. The bearing remnant exhibited severe plastic deformation, with material at the part ends having been folded over onto one side, and material repeatedly rolled over on the other end. Both surfaces of the bushing remnant exhibited gouges and impact marks. This damage was consistent with repeated impact with adjacent components.

Figure 16 shows some other fractured remnants submitted to the NTSB Materials Laboratory. These fragments were all gray in color, with at least one fracture surface. All the fragments were non-magnetic. The fracture surfaces exhibited a dull luster and were erratic in orientation with a rough texture. These features are exemplified in Figure 17. These features were consistent with fracture from overstress fracture. These remnants were consistent with being aluminum fragments from the piston and/or cylinder.

Figure 18 shows the two spark plugs submitted from the #4 cylinder position. The right spark plug on Figure 18a exhibited some dimpling features, consistent with impact from an adjacent object. While there were some dark compounds on the internal surfaces of the plugs and their electrodes, there was no indication of excessive fouling compounds or arcing damage.

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Materials Research Engineer

³ ASTM E384 – *Standard Test Method for Knoop and Vickers Hardness of Materials*. ASTM International, West Conshohocken, PA



Figure 1 – The fragments of the connecting rod from the engine, as received.



Figure 2 – The markings on the web of the connecting rod neck remnant.



Figure 3 – View of the piston pin bore surface remnant on the connecting rod fragment.



Figure 4 – The bore surface in Figure 3, after sectioning.



Figure 5 – The side of the connecting rod pin bore remnant, showing the fractured area with post-fracture batter and impact.

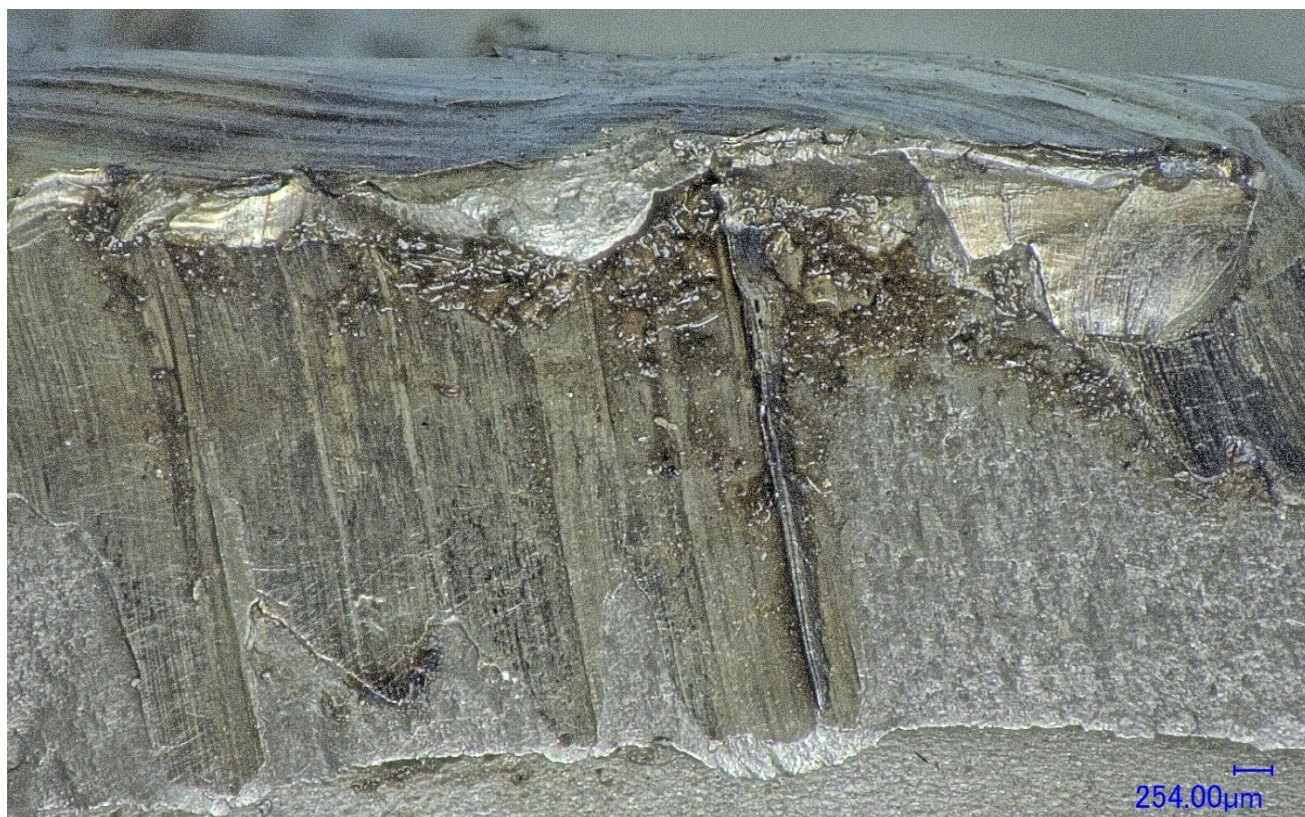


Figure 6 – Closer view of the damaged fracture in Figure 5, showing gouging, impact marks, and heat tinting.



Figure 7 – View of the fracture surface of one of the smaller connecting rod pin bore remnants, showing crack arrest marks consistent with crack propagation from right to left.

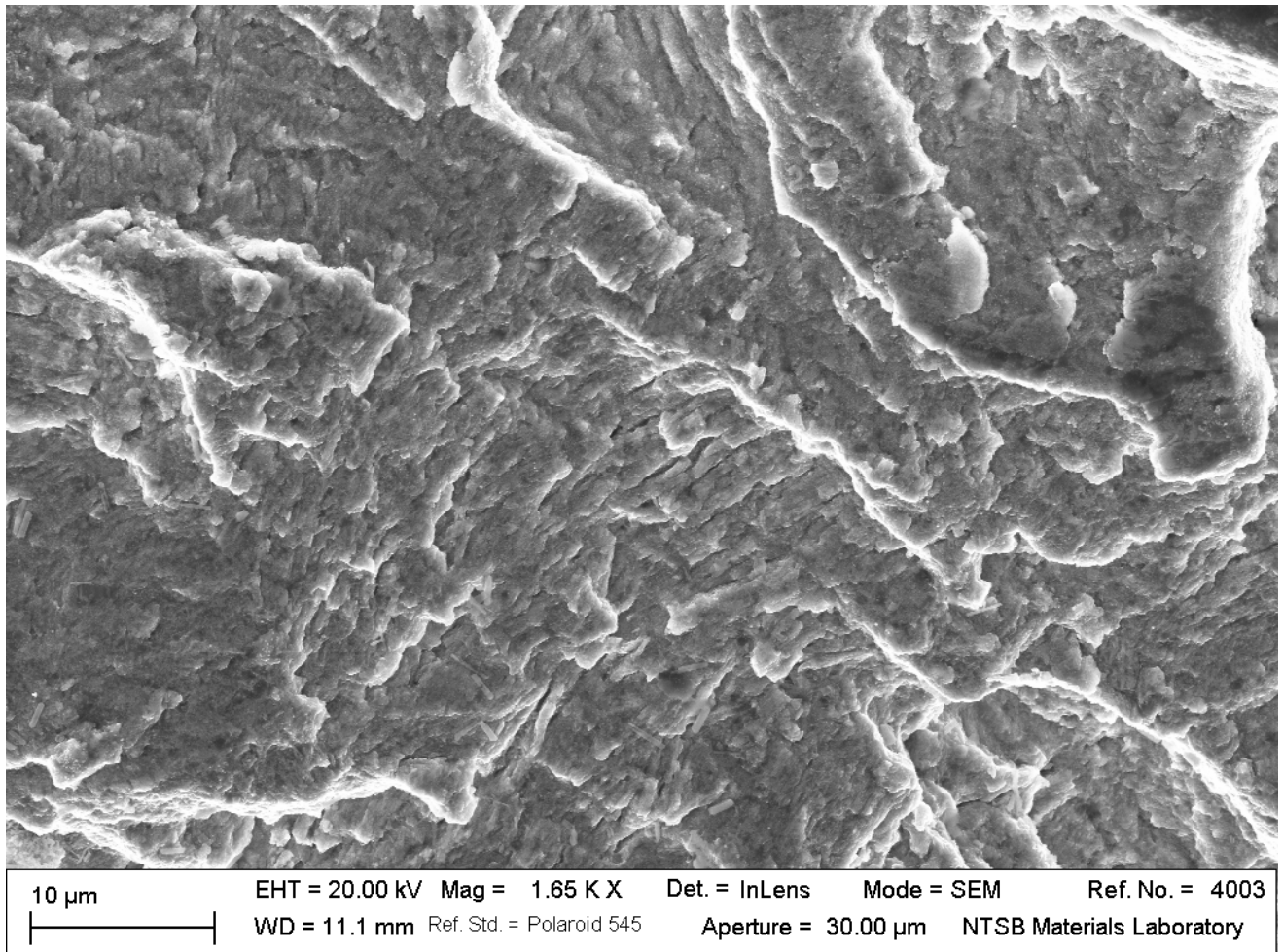


Figure 8 – Secondary electron (SE) micrograph of a typical area of the remnant fracture surface in Figure 7, showing fatigue striations.

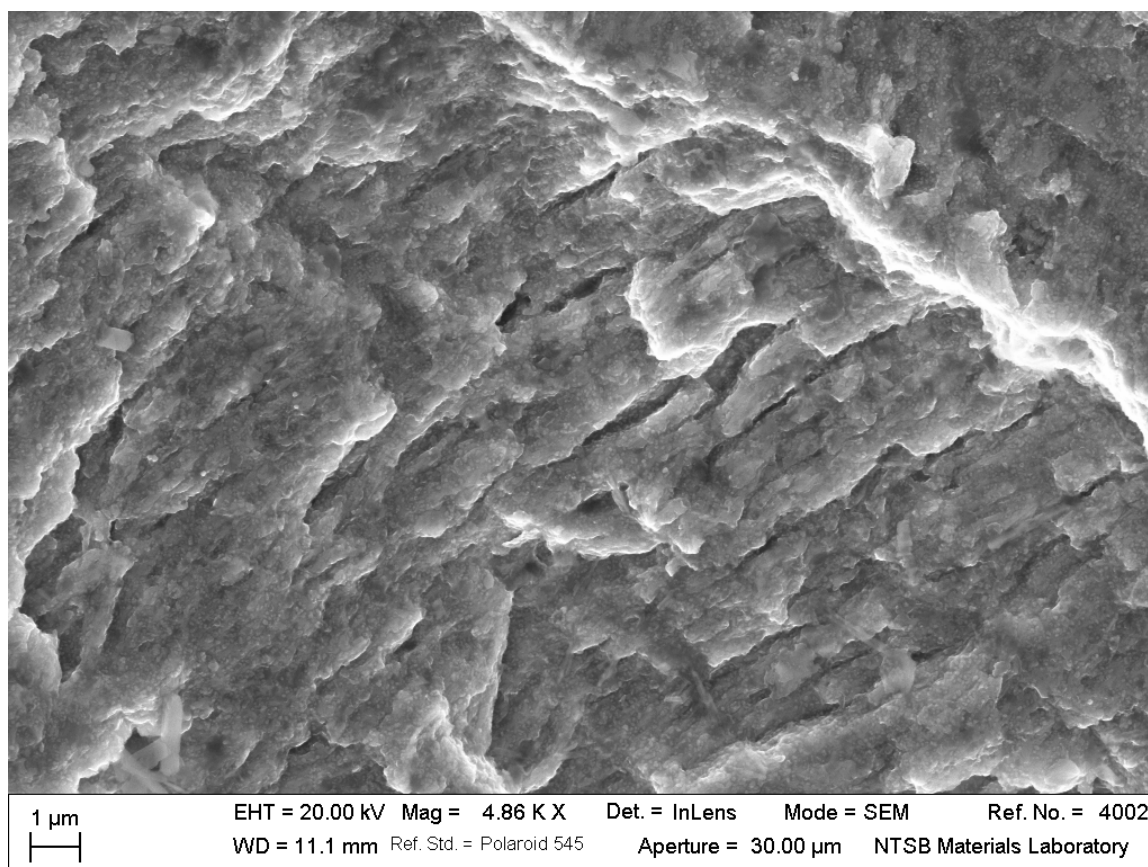


Figure 9 – SE micrograph of a closer view of the fatigue striations in Figure 8.

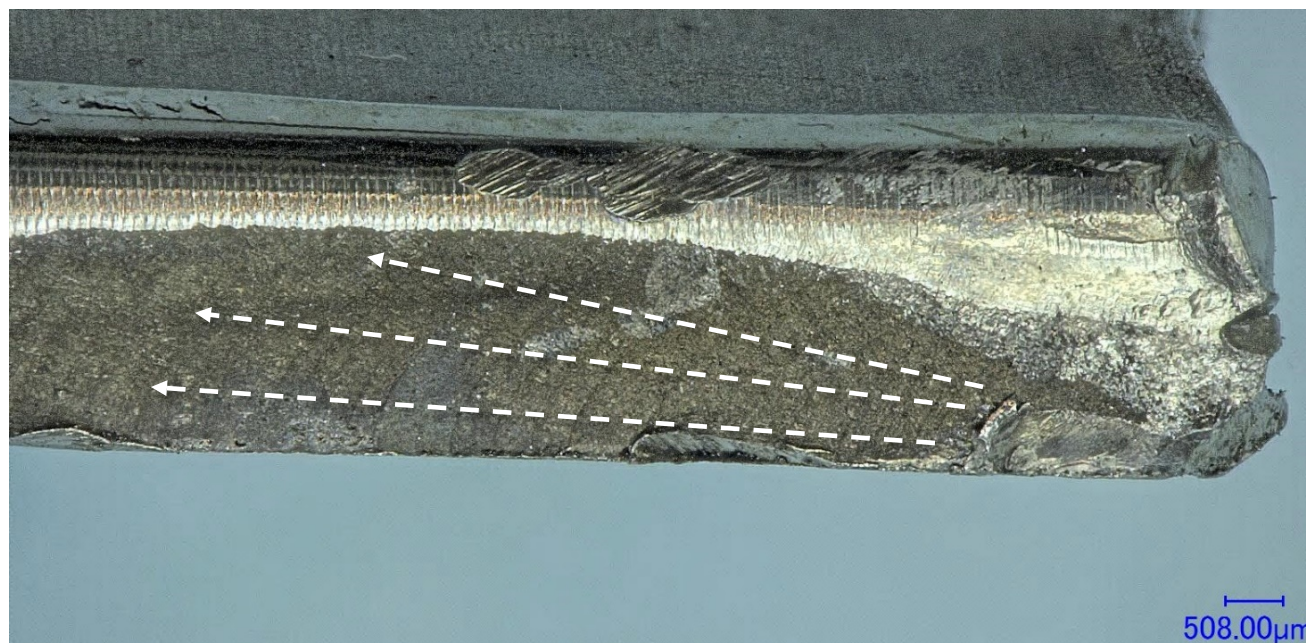


Figure 10 – View of the fatigue crack origin region of the connecting rod remnant. The arrows denote the general crack propagation direction.

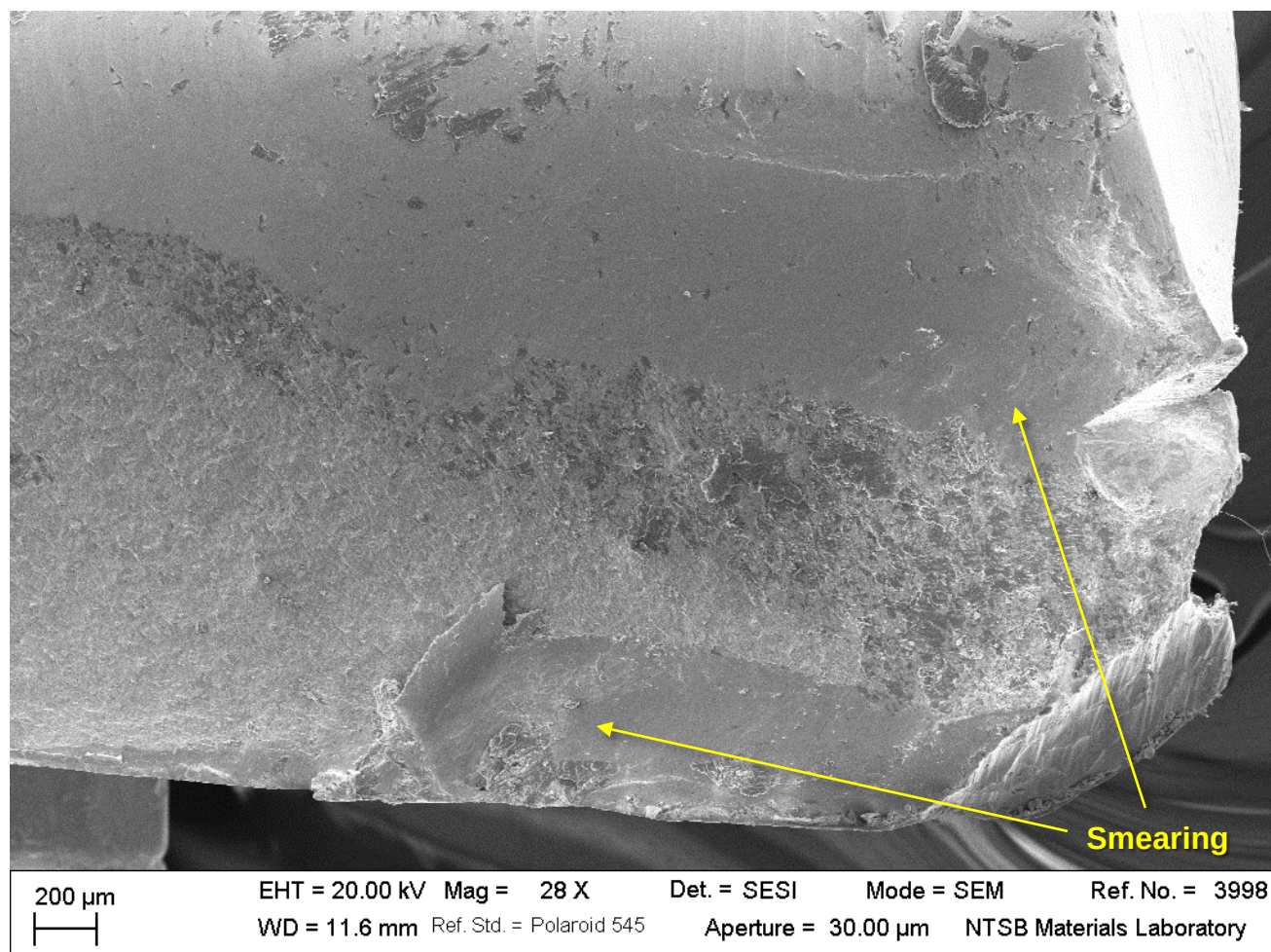


Figure 11 – SE micrograph of the fatigue crack origin area, showing smearing and post fracture damage.

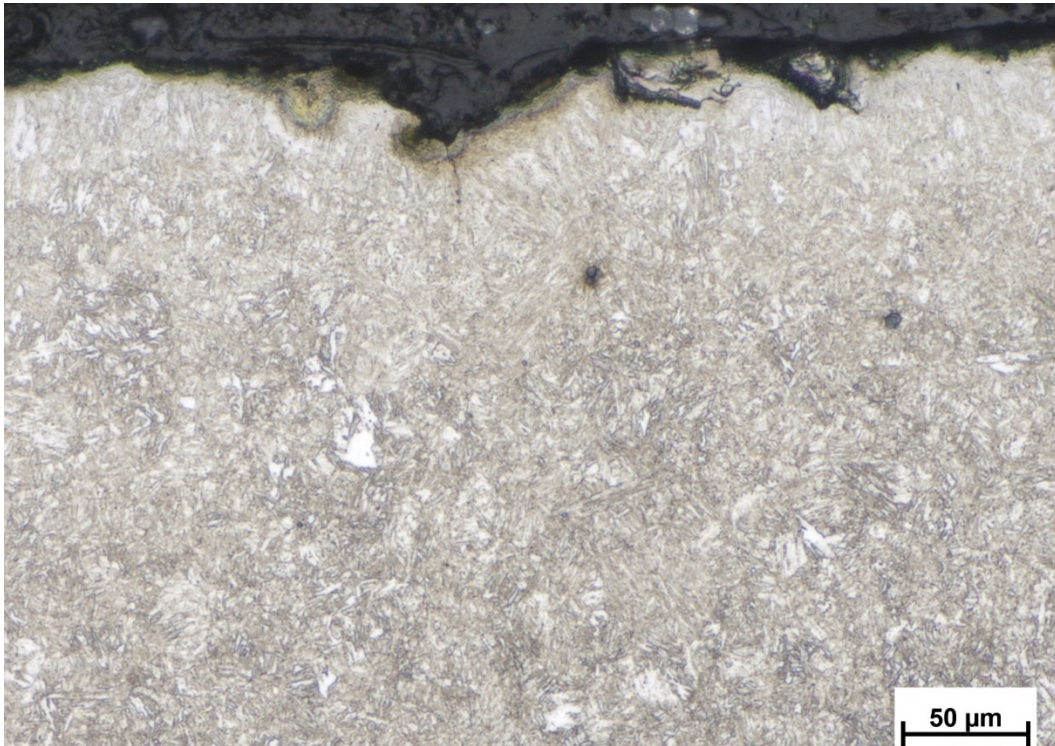


Figure 12 – Bright-field (BF) optical micrograph of a typical cross-section of the surface of the connecting rod remnant, showing a tempered martensite microstructure. (~200X, etched 2% Nital).

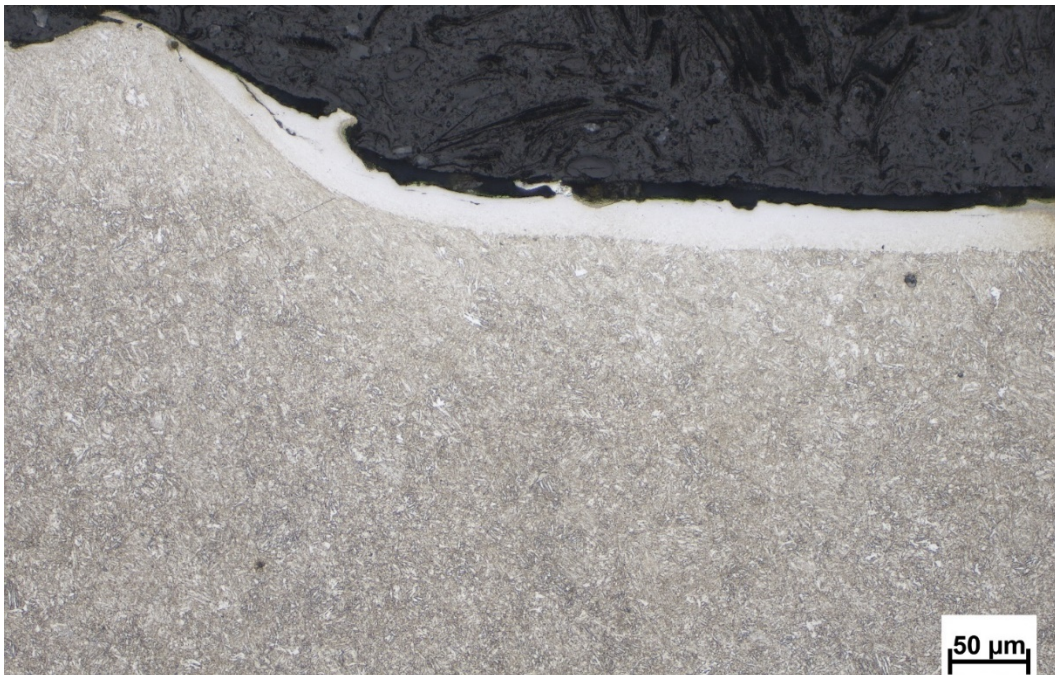


Figure 13 – BF micrograph of part the surface of the connecting rod remnant, showing a surface layer of untempered martensite, consistent with an area that experienced elevated temperatures and rapid cooling (~200X, etched 2% Nital).



Figure 14 – The remainder of the bushing from the connecting rod pin bore, as received.

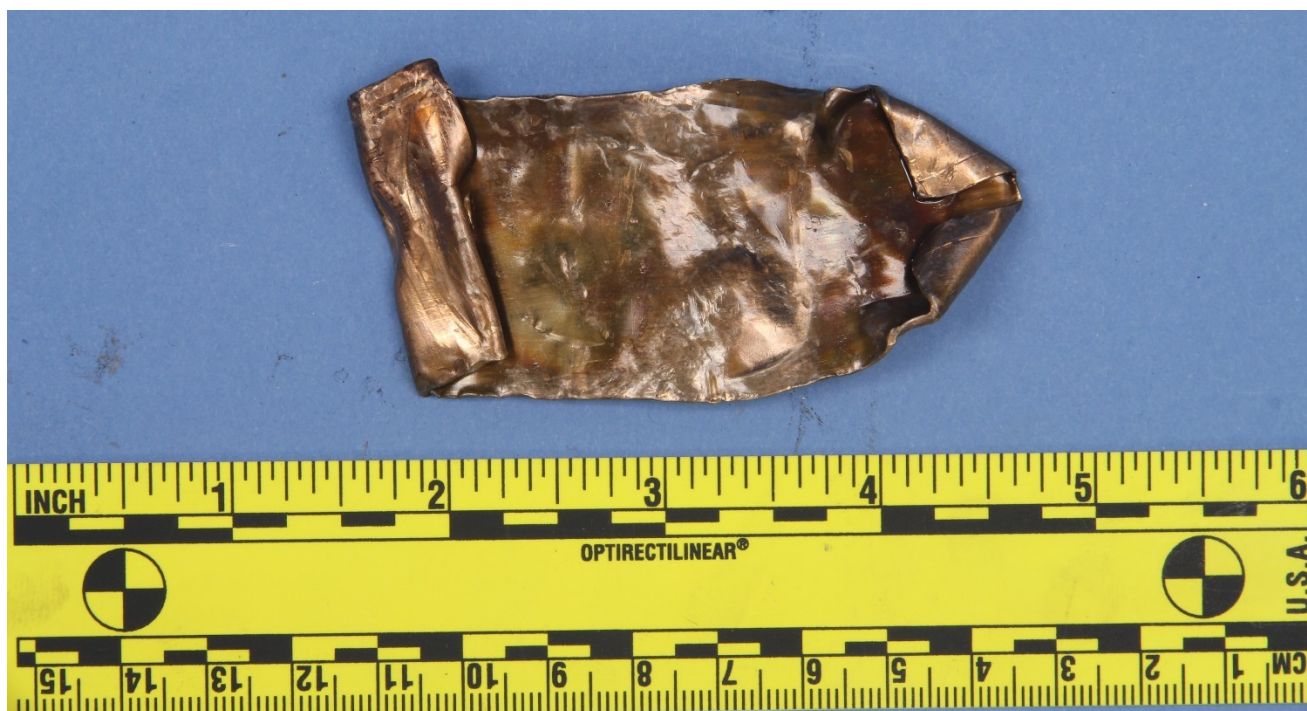


Figure 15 – View of the bushing remnant from the side opposite Figure 14.



Figure 16 – Miscellaneous pieces of the housing submitted with the other engine parts.

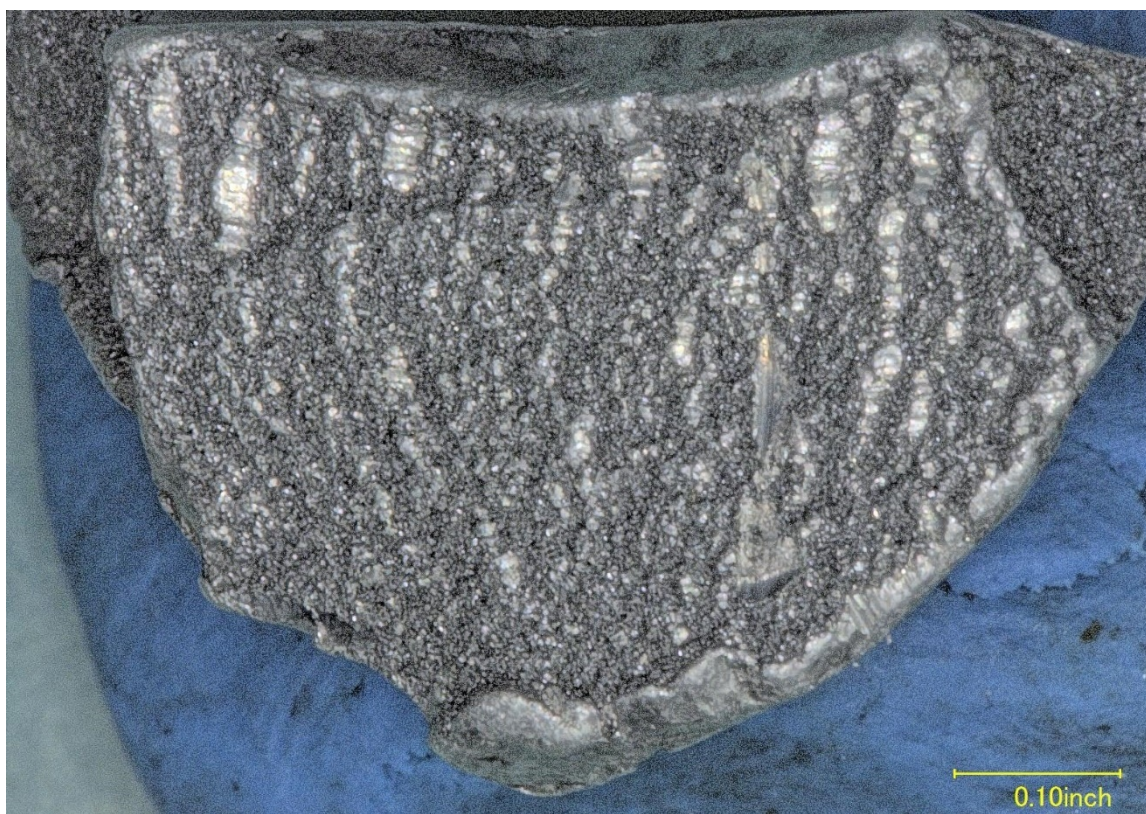


Figure 17 – One of the fracture surfaces of the fragment circled in Figure 16.

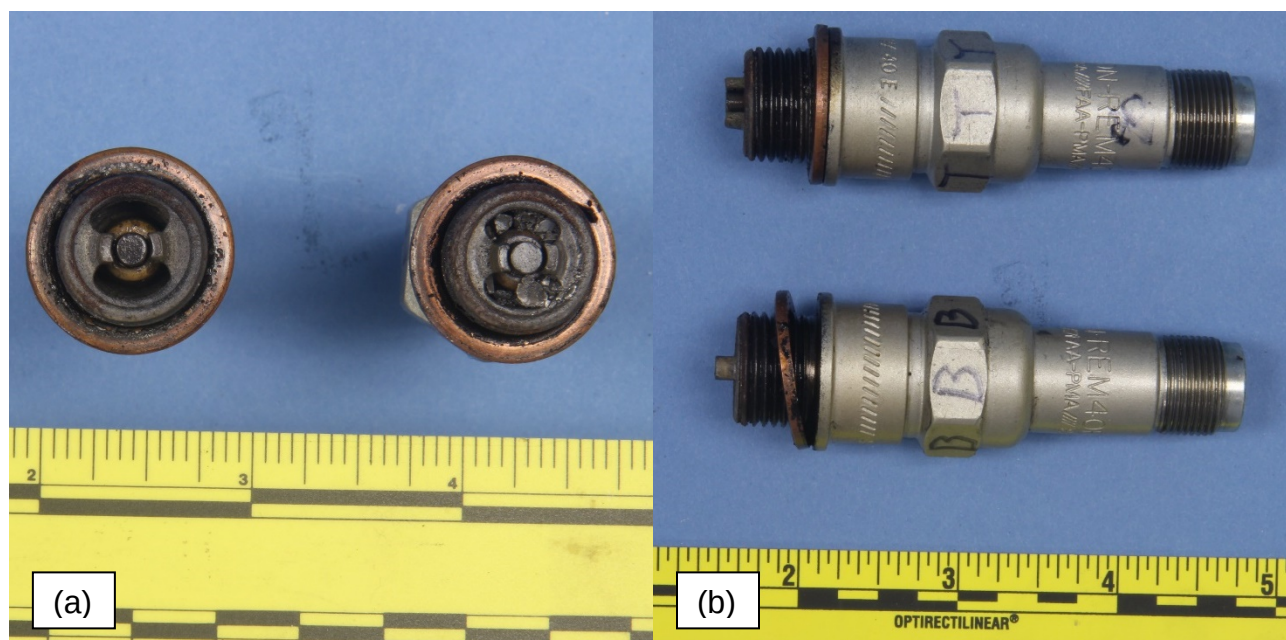


Figure 18 – View of the #4 spark plugs from (a) the electrode and (b) the sides.