

NATIONAL TRANSPORTATION SAFETY BOARD

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



July 23, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 18-051

1. ACCIDENT INFORMATION

Place : Hinesville, Georgia
Date : December 17, 2017
Vehicle : Piper PA-32-300, N4326X
NTSB No. : WPR18LA051
Investigator : Maja Smith, AS-WPR

2. COMPONENTS EXAMINED

Remnant of connecting rod
Piston assembly
Pieces of bearings

3. DETAILS OF THE EXAMINATION

On December 14, 2017 about 0854 eastern standard time, a Piper PA-32-300 was substantially damaged during an emergency landing at Wright Army Airfield near Hinesville, GA. The pilot received minor injuries. In a statement provided to the FAA inspector, the pilot stated that he was on final approach when he felt a shudder followed by a loud bang. Immediately after, the windshield was covered in oil, and the engine experienced a complete loss of power. During the attempted emergency landing, the airplane impacted a tree line. Several components from the Lycoming TIO-540 engine were recovered and sent to the NTSB Materials Laboratory for additional examination.¹

Figure 1 shows the bearing halves from the connecting rod, as received. Both halves, typically circular, had been deformed and flattened. One of the halves was intact whereas the other had fractured. The intact half exhibited markings on the outer surface, stating, "74-09" and "B". The analogous area on the fractured bearing had been smeared such that the only discernible marking was a "B".

Figure 3 shows the fractured portion of the broken bearing half. The fracture was oriented perpendicular to the longitudinal rolling direction of the bearing. The mating fracture surfaces had been heavily damaged and obliterated, obscuring most of the

¹ The TIO-540 is a family of air-cooled six-cylinder, horizontally opposed fixed-wing aircraft and helicopter engines with fuel injection and a turbocharger, made by Lycoming Engines, headquartered in Williamsport, PA.

fracture features. This damage was consistent with post-fracture damage. Portions of the undamaged fracture surface, as exemplified in Figure 3, exhibited features consistent with tensile overstress. The fracture surface exhibited a general rough texture with a dull luster, as shown in Figure 4. The areas adjacent to the fracture surface exhibited local plastic deformation in the form of thinning or necking. These features were consistent with overstress fracture. No features consistent with other fracture modes were observed.

The smaller fractured piece in Figure 3 exhibited a circular indentation, consistent with post-fracture batter. This impression was consistent with impact from the head of a connecting rod bolt.

Figure 5 shows the submitted fragment of a connecting rod bolt. The bolt had fractured about mid length. Figure 6 shows the fracture surface of the bolt. About half of the surface was flat in orientation and exhibited a sharper angled ridge on the other half. The fracture features were generally rough in texture and flat in luster. These features were consistent with fracture from bending overstress.

Figures 7 and 8 show the piston assembly, as received. The piston was intact, with the connecting rod still affixed to piston with the piston pin. The connecting rod had fractured near the crankshaft side at the rod yoke. The connecting rod cap was not received.

The assembly was taken apart by removing the piston pin caps and removing the pin. Figures 9 and 10 show the piston from the underside and from the crown, respectively. There were no cracks or indications of severe deformation on any portion of the piston. The underside of the piston exhibited multiple impact and gouge marks, consistent with repeated batter of adjacent or loose components.

The crown of the piston was of a dimpled configuration, allowing more room for the exhaust and intake valve heads. The piston crown surface exhibited a coating of a brownish-yellow colored, flaky compound. This layer was thick enough that portions had spalled off. These compounds were consistent with compounds that form after combustion of tetraethyl lead and other additives in aviation gasoline (avgas).

The side of the piston is illustrated in Figure 11. The two upper scraper rings and the lower oil ring were in their respective positions in the piston grooves. There was no indication of cracking, excessive wear, or other damage to these components. The side of the piston skirt, as shown in Figure 11, exhibited vertical witness marks. These marks were consistent with sliding wear with the adjacent cylinder wall, or material trapped between the piston and the cylinder.

Figure 12 shows the piston pin after disassembly of the piston and connecting rod. The pin exhibited circumferential wear marks consistent with the location of the connecting rod. The wear marks match those observed in the pin-side bearing bore of connecting rod. The wear pattern on the pin was typical of those in service, and there were no indications of sliding or excessive wear consistent with poor fit or lack of lubrication in this region.

Figure 13 shows the connecting rod fragment from both sides, after disassembly. The side with the markings, in Figure 13a, stated "TW 1-5" "LW-13756". The reverse side, shown in Figure 13b, stated only "F". The portions of the connecting rod along the crankshaft bearing surface were missing and fractured, and much of the connecting rod near the yoke had been severely battered. The sides of the connecting rod above the yoke exhibited batter severe enough to fold material over the flanges of the connecting rod (see upper portions of Figures 13a and 13b).

The fracture surface of the connecting rod was sectioned and cleaned using soapy water and then ethyl alcohol. Figure 14 shows the bearing side of the connecting rod fracture surface. Both tangs were missing, and any fracture features that may have been present were obliterated. Almost all the fracture and bearing surfaces exhibited sharp, angled impressions, consistent with repeated contact with adjacent components.

In order to examine if there were any underlying fracture features or material discrepancies, the battered fracture surface of the connecting rod was sectioned as shown in Figure 15. The sectioned portion was mounted, polished, and etched with a 2% Nital solution.²

Figure 16 shows a typical cross section of the battered fracture surface of the connecting rod. Consistent with the forging direction of the part, the grain flow orientation would be vertical in Figure 16. However, near the battered surface (top of Figure 16), the grain orientation became parallel with the surface, approximately horizontal in the figure. This change in grain flow was consistent with heavy plastic deformation of the part at elevated temperature.

Figure 17 shows a closer view of the battered surface. This shows the changed grain orientation, oriented parallel to the battered surface. In addition, the surface portion exhibited a white-colored layer approximately 0.001-inch thick, containing cracks parallel to the surface. For this material and etchant, the white-colored layer was consistent with untempered martensite. The presence of this microstructure was indicative of the connecting rod bearing surface having reached temperatures more than 1340 °F (727 °C).

Areas away from the fracture surface were also examined. Figure 18 shows a typical section of the connecting rod surface, away from mechanical damage and batter. The surface was rough, exhibiting pit-like features along the surface. A typical area of the interior of the connecting rod is shown in Figure 19. This microstructure was consistent with tempered martensite, the expected and typical microstructure for this component.

The composition of the connecting rod was inspected using EDS and x-ray fluorescence (XRF). The composition was consistent with Type 4000- or 8000-series alloy steel. The hardness of the shaft was inspected per ASTM E384.³ The hardness averaged

² Nital is a solution consisting of 2% nitric acid (HNO₃) and methanol, used specifically to etch microstructural features in steels.

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

32 HRC (318 HV₅₀₀). This hardness was typical of steel alloys for the chemical composition and microstructure observed.

The hardness near the surface was inspected to determine if there may have been significant decarburization of the connecting rod.⁴ Figure 20 shows a plot of microindentation hardness values versus distance. While the area adjacent to the surface exhibited a lower hardness, this did not persist past 0.005 inches into the surface—consistent with partial decarburization.

A bag with small pieces of fractured debris was submitted. Figure 21 shows these debris fragments, after cleaning with acetone. These pieces were consistent with either steel or aluminum alloys. The discernible fracture features were examined using optical microscopy. All the fracture surfaces with discernible features exhibited features that were consistent with overstress fracture. There were no indications of other fracture modes present on these pieces.

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⁴ Decarburization is a loss of carbon from the surface layer of a carbon-containing alloy due to a reaction with one or more substances (such as oxygen) in the surrounding atmosphere.



Figure 1 – The pieces of both halves of the connecting rod bearing, as received, from the (a) inner bearing surface and (b) outer bearing surface.

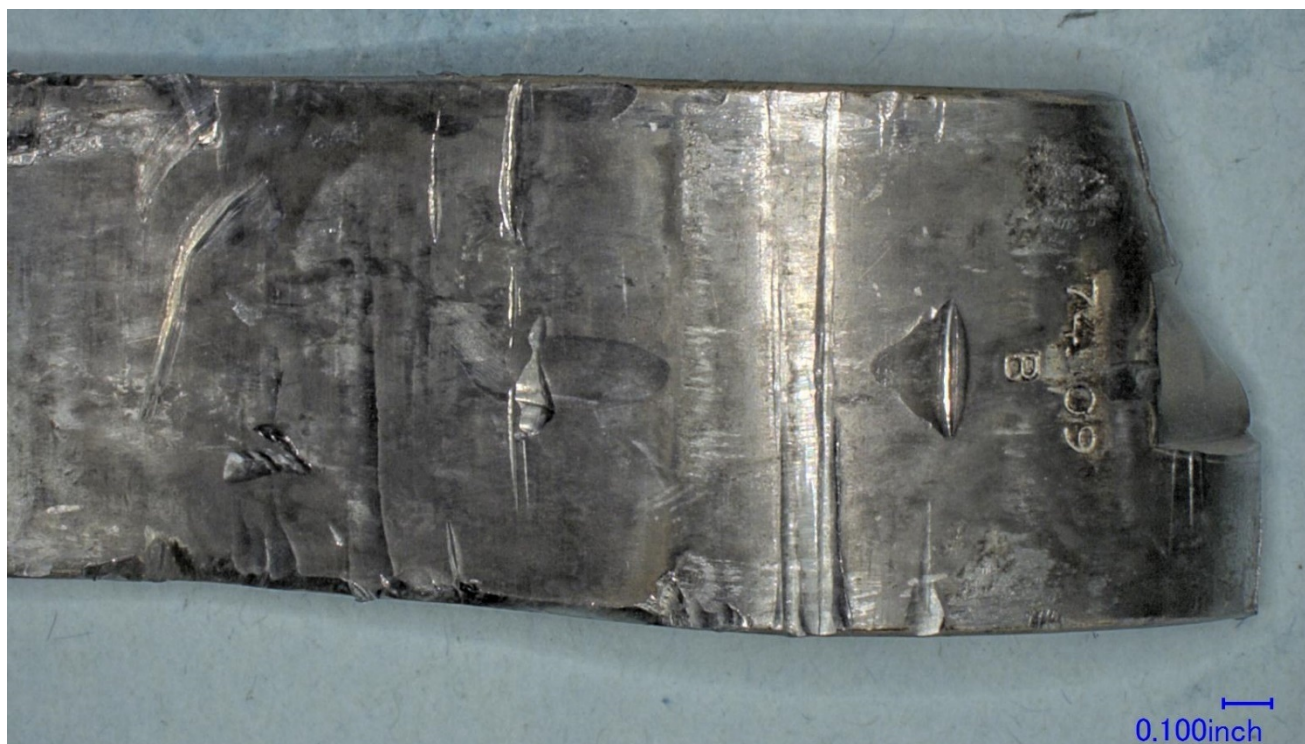


Figure 2 – View of the end of the intact bearing half from the outer surface, showing identification marks, impact marks, and inward deformation.



Figure 3 – The mating fracture faces of the fractured bearing half, showing a circular impact imprint.

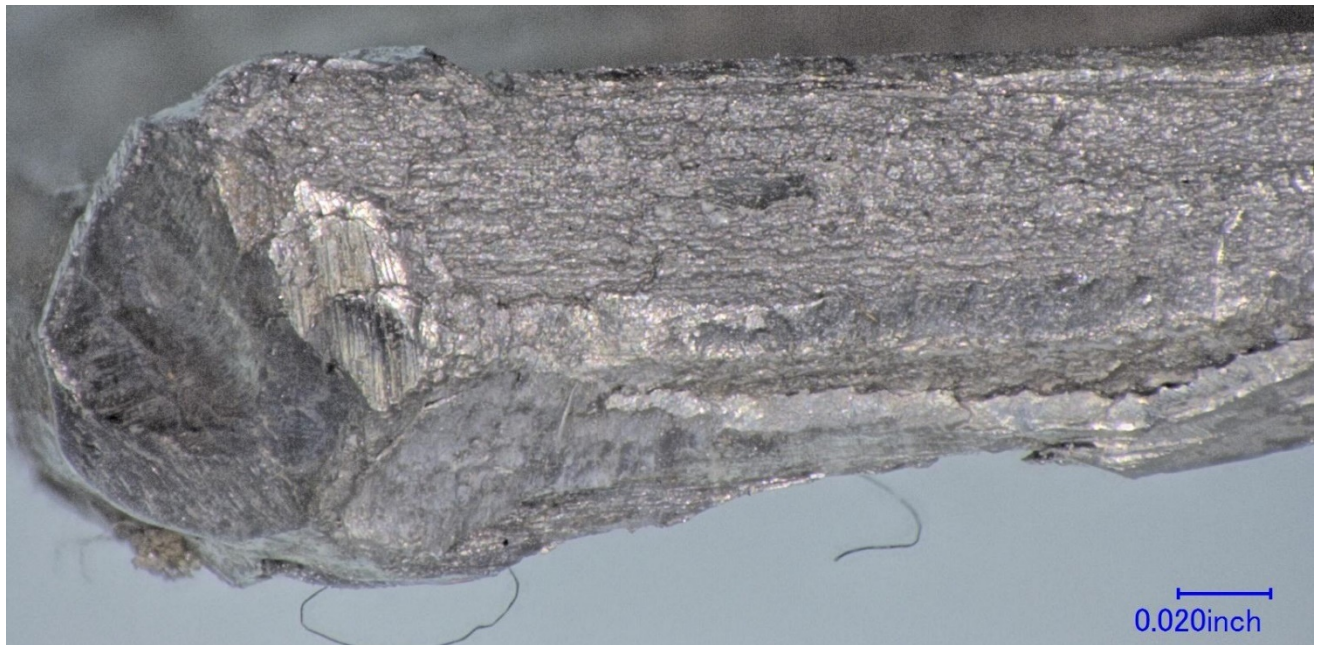


Figure 4 – Closer view of one of the bearing fracture surfaces from Figure 3.



Figure 5 – Side view of the fractured connecting rod bolt, as received.

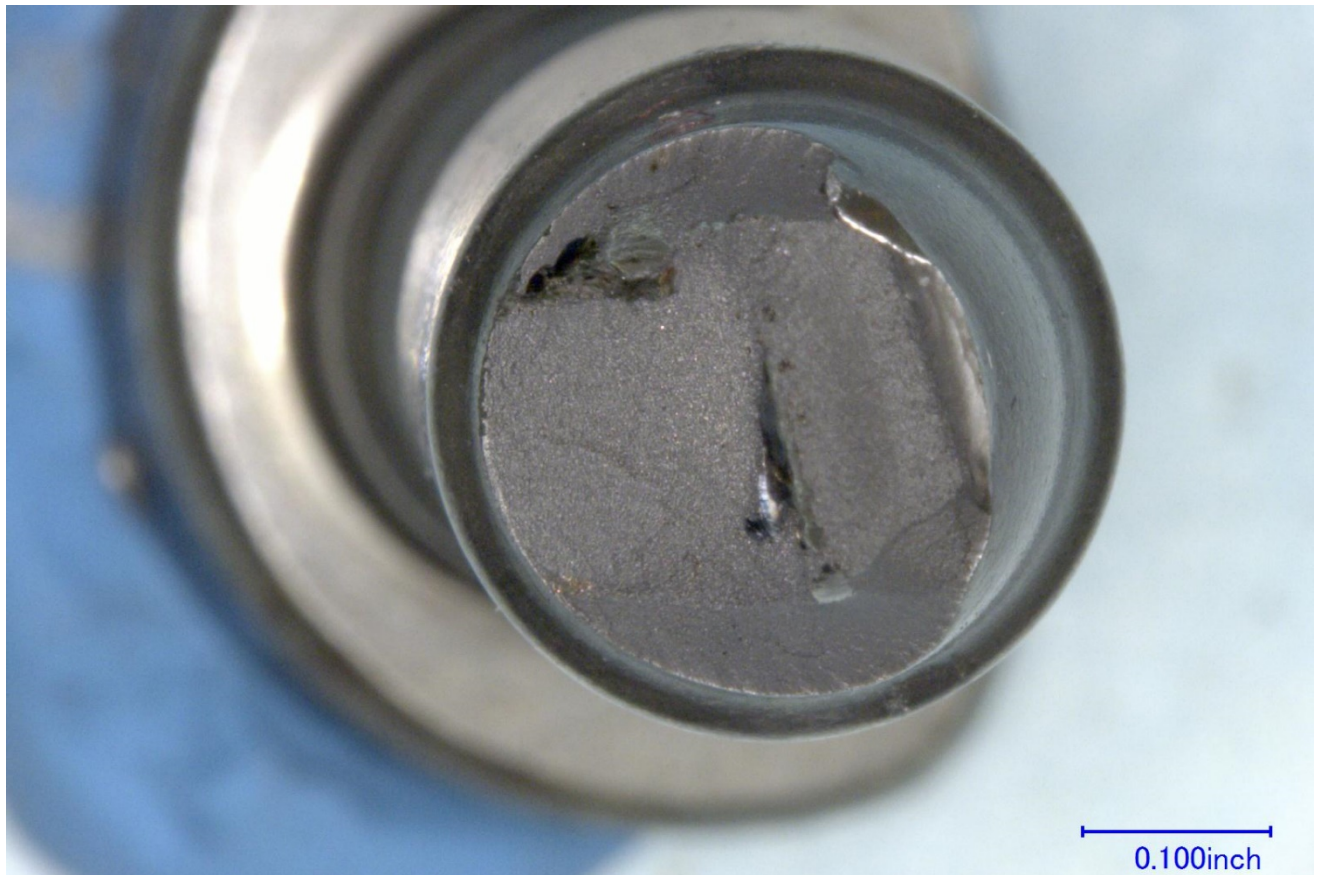


Figure 6 – The fracture surface of the connecting rod bolt, showing a deformed ridge on the right side.



Figure 7 – The underside of the piston assembly, with the connecting rod fragment still attached via the piston pin.



Figure 8 – Reverse view of Figure 7, showing the crown of the piston and the other batter damage to the connecting rod.



Figure 9 – Underside of the piston, after disassembly.



Figure 10 – The crown of the piston, after disassembly.



Figure 11 – The side of the piston, after disassembly, showing the scraper and oil rings, and vertical scuff marks on the piston skirt.

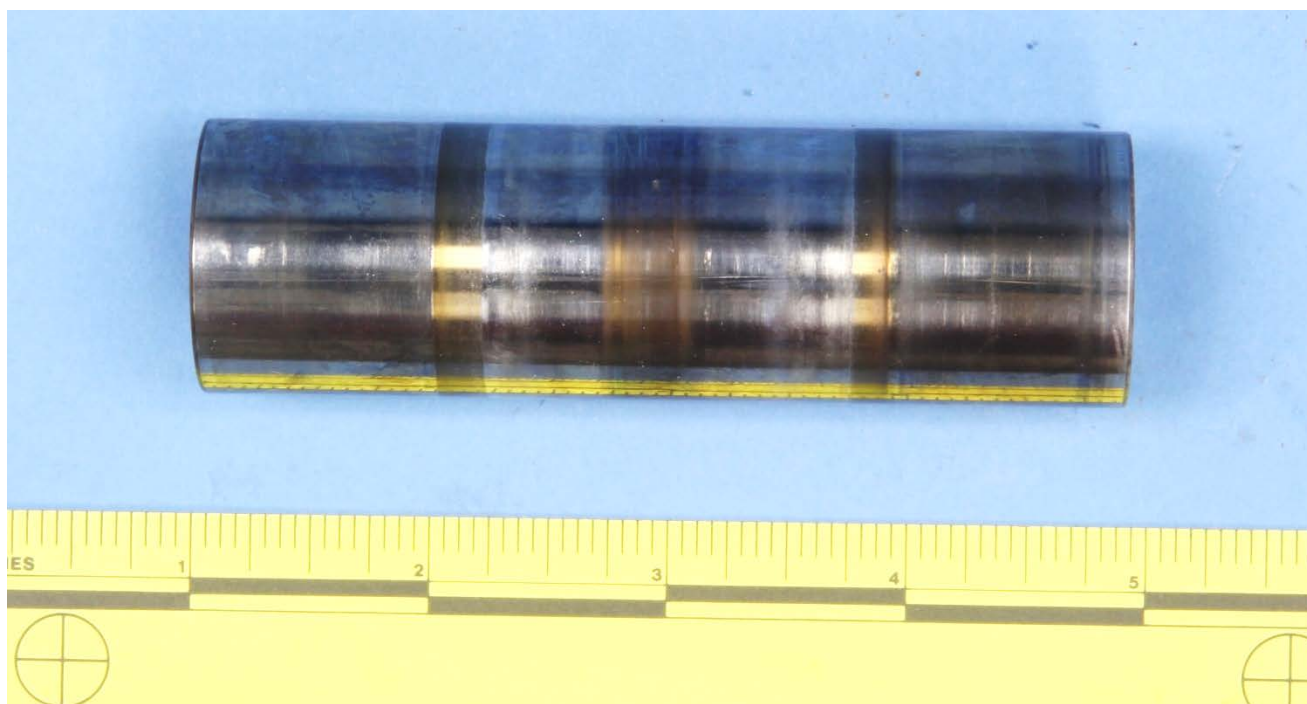


Figure 12 – The piston pin, after disassembly.



Figure 13 – The connecting rod after removal from the piston assembly from (a) the side with markings and (b) the reverse side.



Figure 14 – View of the battered fracture surface of the connecting rod from the bearing surface.

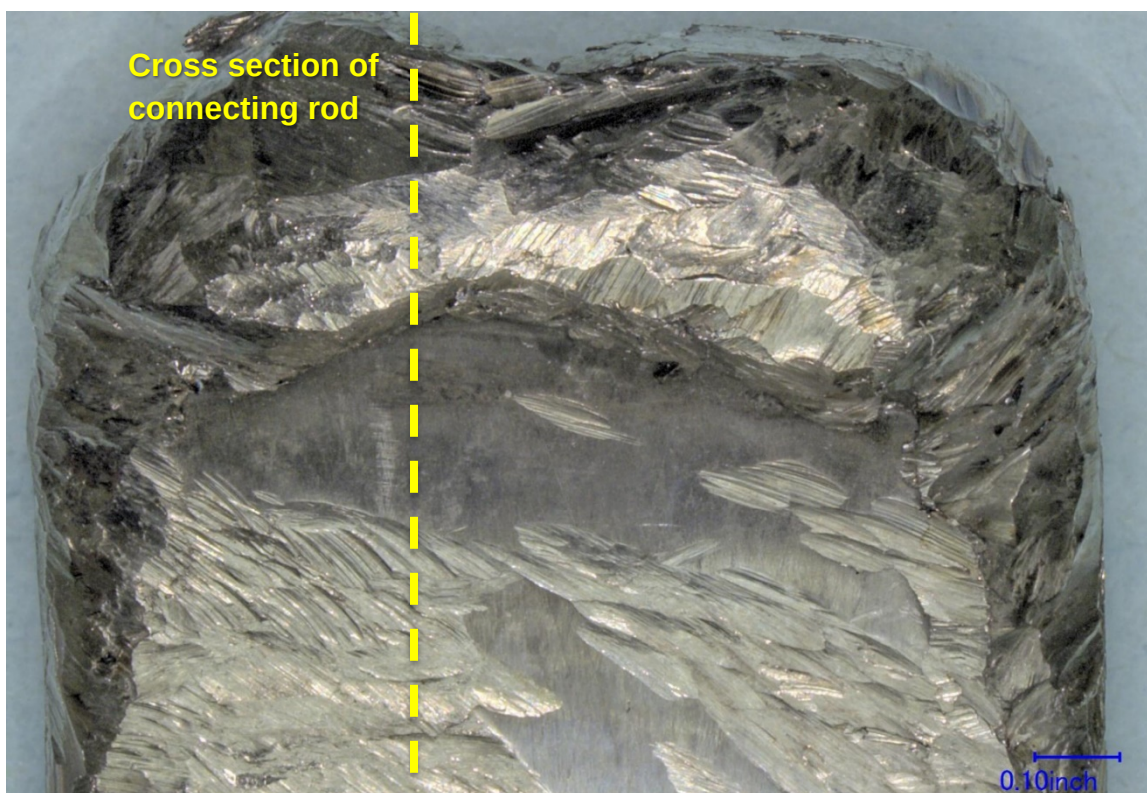


Figure 15 – Closer view of the battered connecting rod fracture, showing the location of the metallographic cross section through the part.



Figure 16 – Bright field (BF) optical micrograph of the cross section in Figure 15, showing grain flow from severe deformation, and a surface white layer (~50X, etched 2% Nital).



Figure 17 – BF micrograph showing the surface in Figure 17, showing grain flow perpendicular to the forging direction of the connecting rod, and white layer consistent with untampered martensite (~200X, etched 2% Nital).

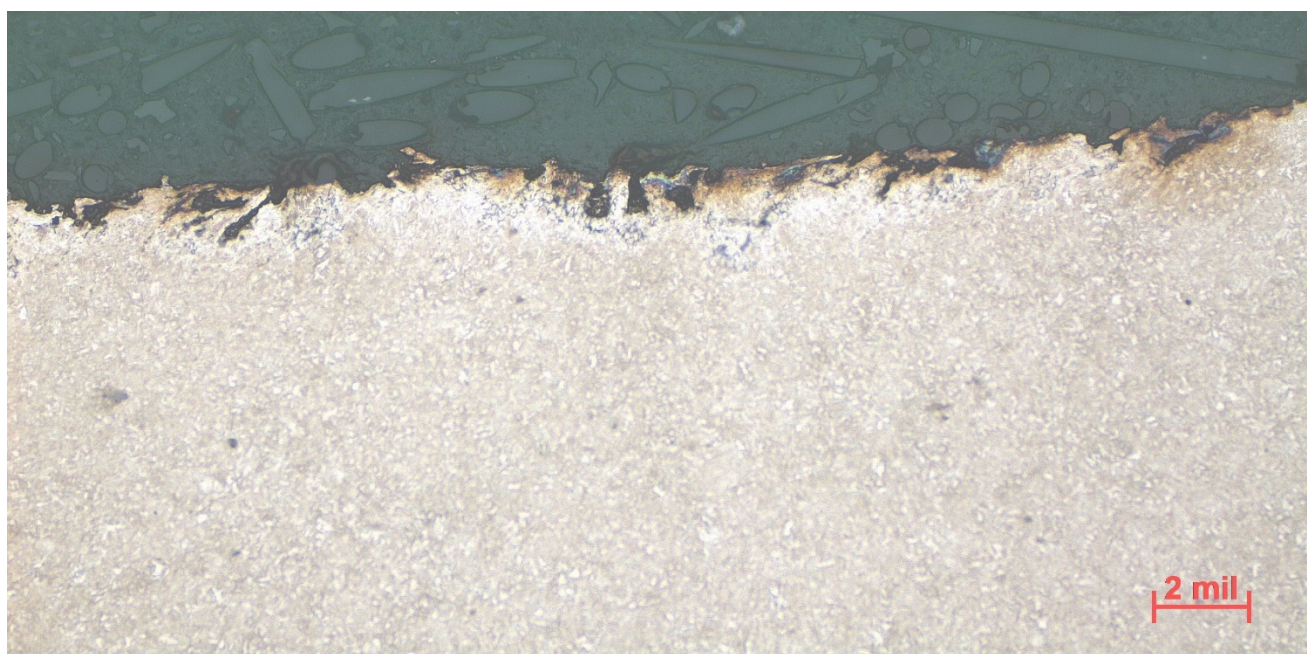


Figure 18 – BF micrograph below the bearing surface of the connecting rod, showing surface pitting and discontinuities (~200X, etched 2% Nital).

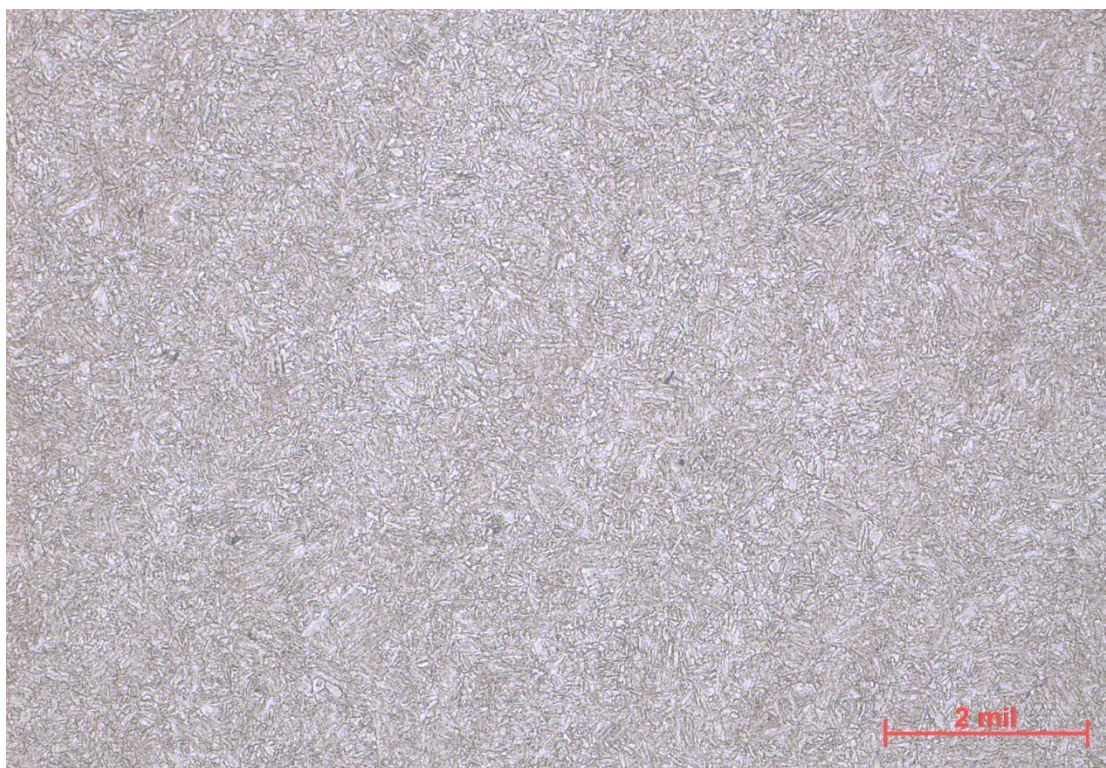


Figure 19 – BF optical micrograph of a typical area of the connecting rod microstructure, showing tempered martensite (~500X, etched 2% Nital).

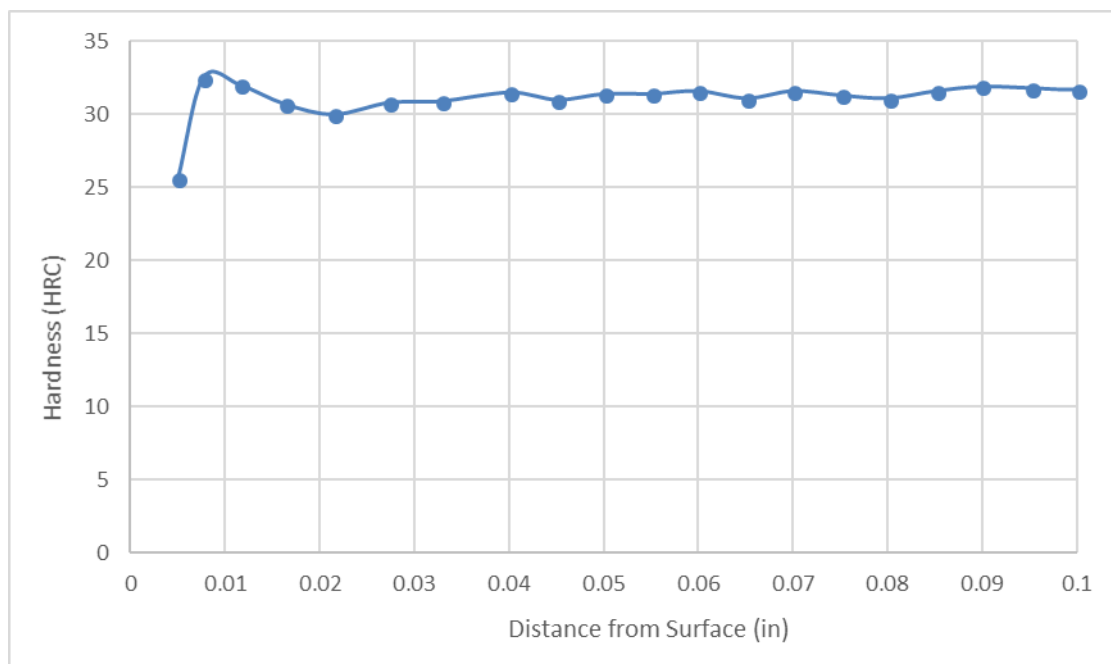


Figure 20 – Chart showing the change in hardness (in HRC) with depth from the surface (in inches) of the connecting rod mounted and polished cross section.



Figure 21 – View of the fragments from the bag of debris, shown after cleaning with acetone.