

NATIONAL TRANSPORTATION SAFETY BOARD

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



September 6, 2017

MATERIALS LABORATORY FACTUAL REPORT

Report No. 17-064

1. ACCIDENT INFORMATION

Place : The Dalles, Oregon
Date : March 31, 2017
Vehicle : Zenith 601XL-B, N610TT
NTSB No. : WPR17LA082
Investigator : Samantha Link, AS-WPR

2. COMPONENTS EXAMINED

Fragments of propeller bolts

3. DETAILS OF THE EXAMINATION

On March 31, 2017 about 1455 Pacific daylight time, a 601XL-B airplane experienced a partial loss of engine power and the pilot subsequently made a precautionary landing about one mile southeast of the Columbia Gorge Regional/The Dalles Municipal Airport (DLS). The commercial pilot and one passenger sustained minor injuries, and the airplane was substantially damaged throughout. According to the pilot, when the airplane was climbing through 3,500 feet, the pilot heard the engine noise change and observed a loss of RPM along with high exhaust gas temperature readings.

The six propeller bolts were sent to the NTSB Materials Laboratory for examination. Figure 1 shows the six bolts, as received. The bolts were labeled 1 through 6 for the purposes of this report.

All of the submitted bolts had fractured in the 13th to 15th thread root from the base of the bolt. This was, on average, 0.69 inches from the base of each bolt. The fracture surfaces were oriented 90° to the longitudinal direction of the bolt, with no gross plastic deformation present adjacent to the fracture surfaces.

Figure 2 shows representative bolt fracture surfaces, as received. The general features of each of the six fracture surfaces were consistent with each other. As typified in Figure 2b (Bolt 2), the fracture surfaces exhibited opposite-facing flat thumbnail-shaped regions with a middle rougher region.

The thumbnail regions exhibited crack arrest, or beach, marks. The orientation of these crack arrest marks was consistent with propagation inward from the surface of the

thread roots. The thumbnail regions also exhibited ratchet marks near the thread root surfaces, consistent with multiple crack initiation sites. These features were all consistent with fatigue in reverse bending.

The fracture surface of Bolt 2 was examined using a scanning electron microscope (SEM). The thumbnail regions exhibited fatigue striations, consistent with fatigue crack propagation from the surface of the bolt (thread root) inward (see Figure 3). The intermediate region exhibited dimple rupture, consistent with overstress failure. These features were consistent with fatigue cracks initiating at the thread root surface, propagating inward due to reverse bending stresses, until the remaining cross-section succumbed to overstress. This pattern was consistent on all of the bolt fracture surfaces.

A metallurgical cross section of Bolt 6 was prepared and examined by optical microscopy. Figure 4 shows a typical region of the bolt microstructure. The microstructure shows a lath structure with uniformly-dispersed fine carbide precipitates, consistent with a tempered martensite structure. Occasional manganese sulfide inclusions were also present.

The chemical composition of the bolt was examined using x-ray fluorescence. The chemical composition was consistent with an alloy steel. The hardness was inspected per ASTM E18.¹ The hardness averaged 36 HRC, which was consistent with values typically reported for this alloy composition and microstructure.²

One of the bolt threads is illustrated in Figure 5. The contact face shows a crack on the flank that would have been in contact with the attachment nut. This thread flank faced the bolt head (labeled in Figure 5). Most of the threads exhibited this type of cracking, consistently located on the contact flank.

Figure 6 shows an area near a thread root. The microstructure exhibited flow lines around the root, consistent with the threads being rolled into the bolt.

Erik Mueller
Materials Research Engineer

¹ ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

² J.R. Davis, ed. "Tool Steels." *Metals Handbook: Desk Edition, 2nd Ed.* Materials Park, OH: ASM International (1998) pp. 346-351



Figure 1 – The six fractured propeller bolts, as received.

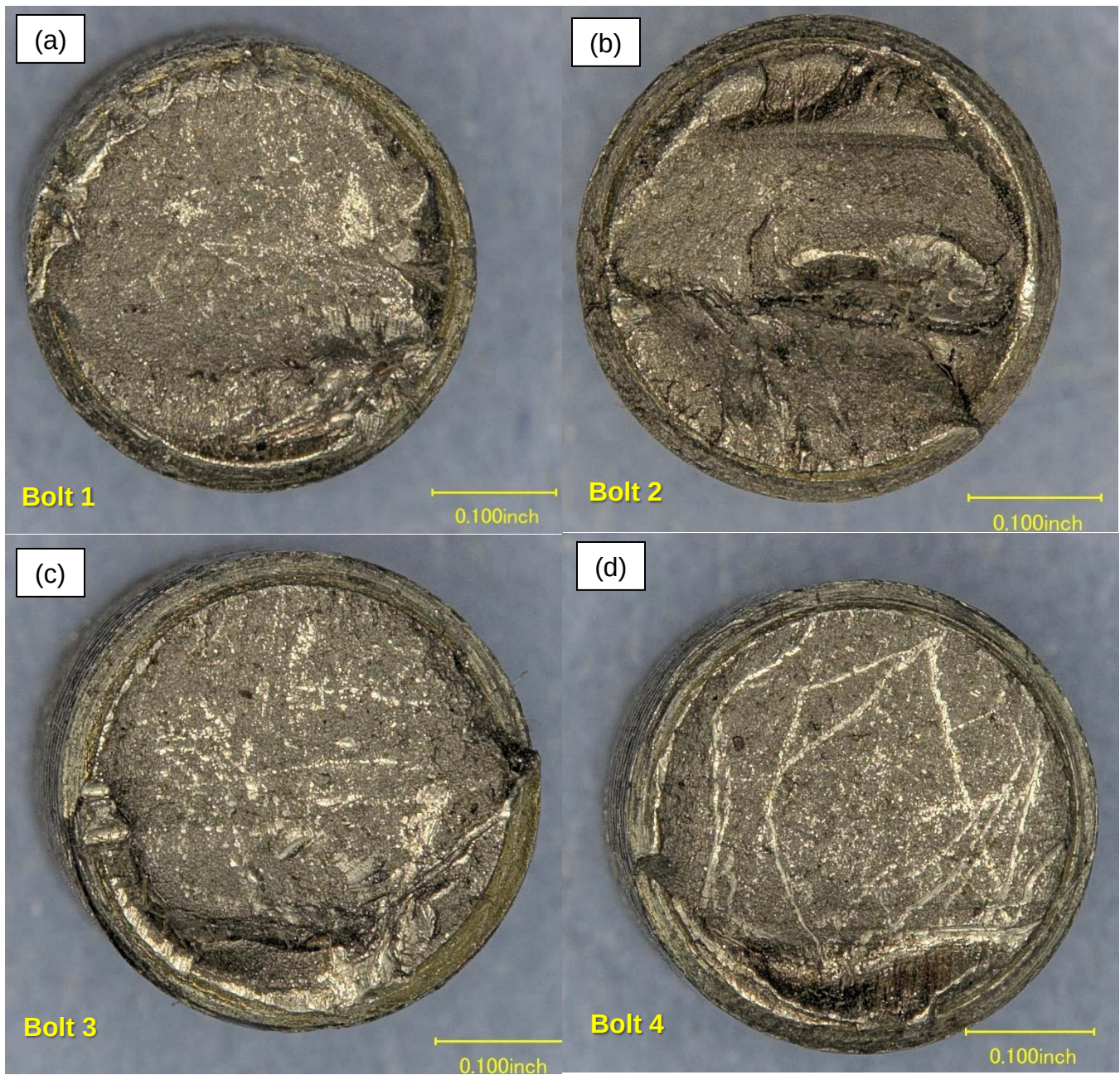


Figure 2 – Selected bolts fracture surfaces of bolts 1 through 4, as received.

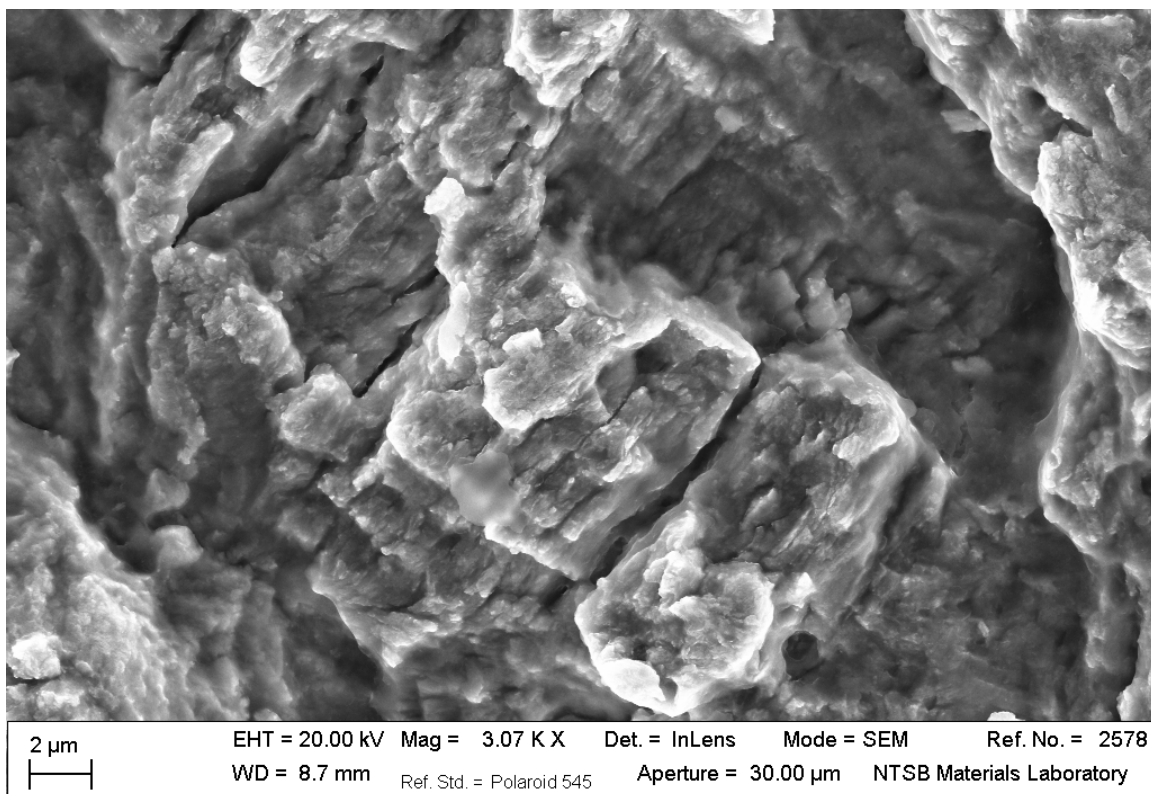


Figure 3 – Secondary electron (SE) micrograph of fatigue striations on the bolt 2 fracture surface.

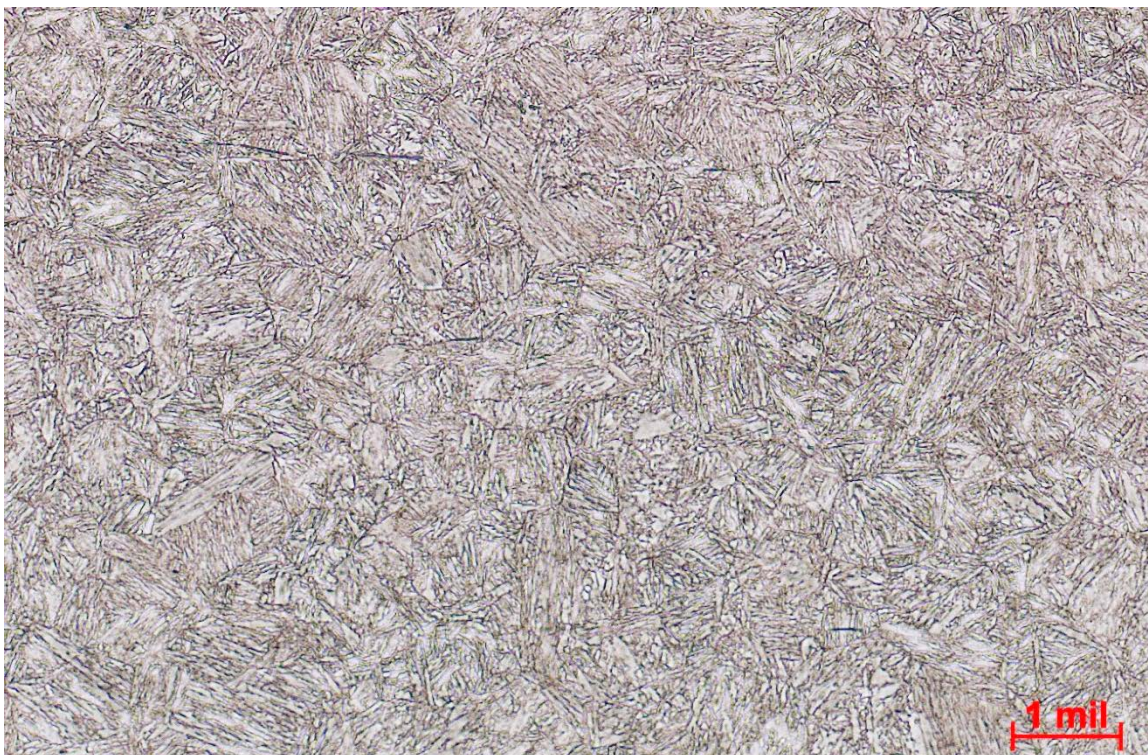


Figure 4 – Bright field (BF) optical micrograph showing the tempered martensite microstructure of bolt 6 (~500X, etched 2% Nital).

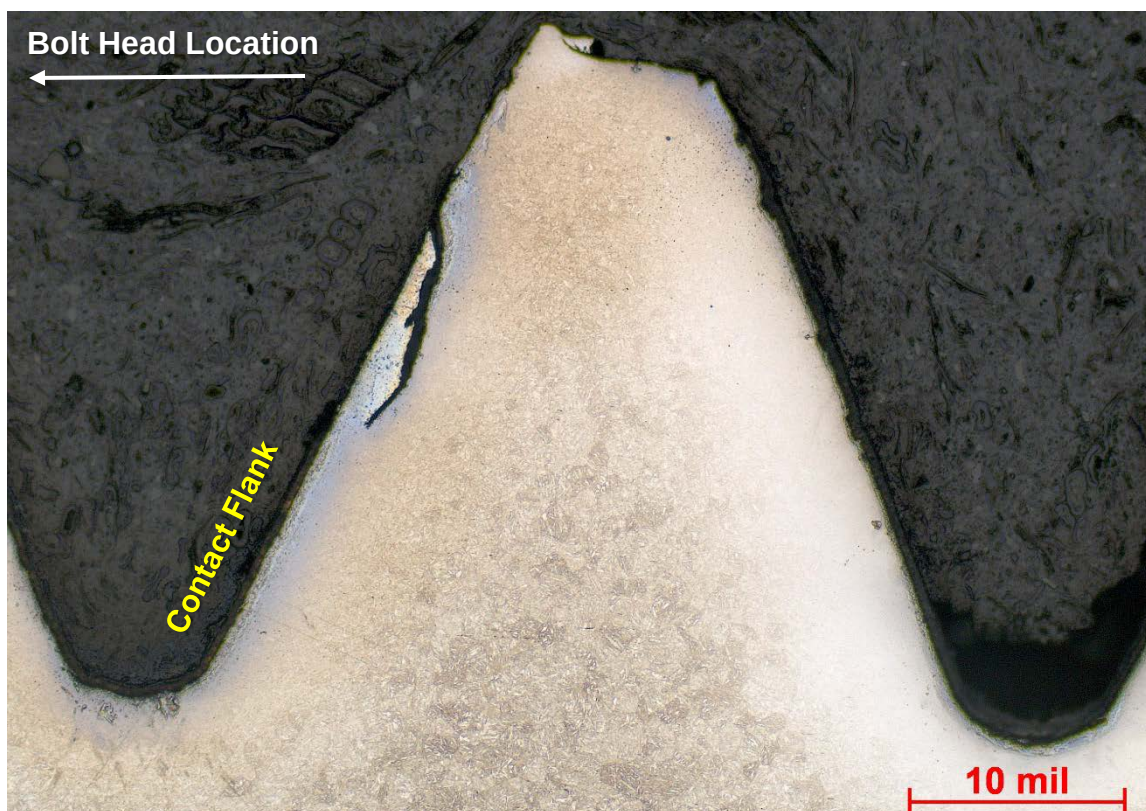


Figure 5 – BF optical micrograph of a thread cross-section in bolt 6, showing a crack on the contacting face (~100X, etched 2% Nital).

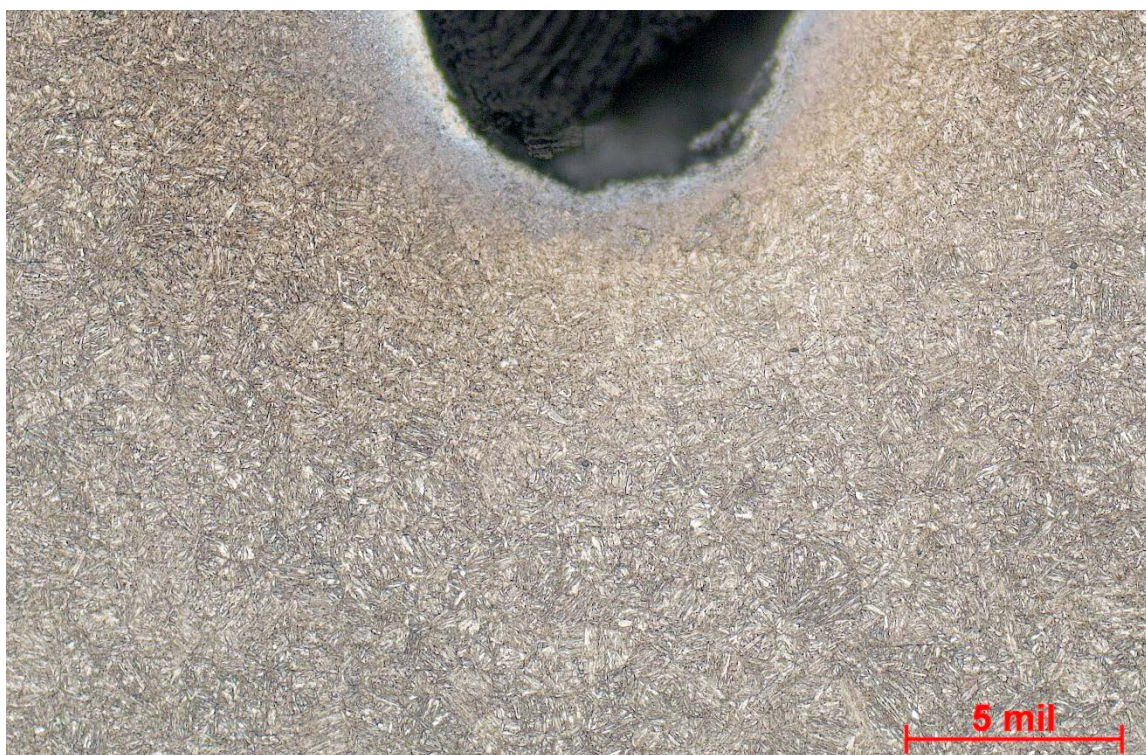


Figure 6 – BF micrograph showing a bolt 6 thread root flow lines (~200X, etched 2% Nital).