

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN24LA342

MATERIALS LABORATORY

Factual Report 25-004

January 31, 2025

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A. ACCIDENT INFORMATION

Location: Crystal, Minnesota
Date: September 4, 2024
Vehicle: Piper PA-28R-200, N4081S
Investigator: Michael Hodges, AS-CEN

B. COMPONENTS EXAMINED

Pieces of the engine mount

C. EXAMINATION PARTICIPANTS

Specialist Matthew R. Fox, Ph.D.
NTSB
Washington, DC

D. DETAILS OF THE EXAMINATION

An overall view of the submitted engine mount pieces is shown in figure 1. The pieces consisted of segments of the tubular structure and attachment feet from the attachment location at the upper aft end of the nose landing gear downlock link and brace assembly and had been cut from the remainder of the engine mount. A tubular frame member was fractured at the upper side of the right attachment foot as indicated in figure 1. The frame members connected to the left attachment foot were intact.

Closer views of the fracture at the upper side of the right attachment foot are shown in figure 2. An angled tube was welded to the left side of the fractured tube just above the fracture location, and both the angled and fractured tubes had been cut approximately 3 inches away from the fracture surface. Greasy deposits were observed covering the black painted surfaces over most of the fractured tube's exterior surface. On the interior of the fractured tube, an accumulation of greasy mostly black deposits of corrosion products and other debris was observed inside the tube piece that remained attached to the foot as shown in the upper right image in figure 2. Similar greasy deposits and accumulations of debris were observed around the inside circumference of the mating side of the fracture as shown in the lower right image in figure 2. A dark rounded film extended across the interior of the fractured tube approximately $\frac{1}{4}$ inch above the fracture surface, and orange oxide flakes extended radially inward from interior surfaces between the fracture surface and the rounded film.

A wood rod was used to scrape deposits from the interior surfaces above the fracture location into a collection dish. The greasy deposits were tacky as the deposits were removed from the interior surfaces. The orange flakes and the dark

rounded film easily broke away from the walls with minimal effort and were also collected into the collection dish. On the exterior surfaces, tacky black deposits above the fracture were scraped from the surface using a nylon scraper and were collected into separate dish. After the samples had been collected from the interior and exterior surfaces, the piece with the upper side of the fracture was placed in a degreasing tank for approximately two hours. Next, the piece was cleaned using an ultrasonic cleaner while submerged in a solution of Alconox detergent and warm water.

A view of the upper fracture surface after cleaning is shown in figure 3. The interior surface above the fracture was oxidized with black, red, and orange oxides. The tube wall showed thickness loss consistent with corrosion damage, which was most extensive on the left half of the circumference. Figure 4 shows an area of wall loss in the aft left quadrant where the remaining fractured wall thickness was 0.007 inch at the location indicated. In the forward left quadrant shown in figure 5, a pit extended nearly through the tube wall at the location shown with an unlabeled arrow. For comparison, the wall thickness as measured at the cut location on the upper end of the same tube was 0.034 inch.

The fracture surface generally showed substantial damage from oxidation and post-fracture contact. However, areas with relatively flat features in planes perpendicular to the tube axis were observed in several locations mostly on the left half of the fracture such as the areas shown in figures 4 and 5. Additional features including radial lines and ratchet marks such as those indicated in figure 4 were also observed in these areas emanating from the interior edge of the fracture. These fracture features were consistent with fatigue initiating from corrosion pits at the interior surface of the tube. The fatigue regions had multiple origins at locations indicated with unlabeled brackets in figure 3. The fatigue regions appeared to extend through the wall thickness in the aft fatigue region and the left half of the forward fatigue region. At the forward right side of the fracture, the fatigue region extended part way through the thickness to the indicated fatigue boundary. The circled area at the left side of the fracture was smeared from post-fracture damage, so the fracture mechanism was undetermined in that area. The remainder of the fracture surface outside of the fatigue boundary and to the right of the fatigue regions had rough features on slant angles consistent with ductile overstress fracture.

The fracture was further examined using a scanning electron microscope (SEM). A montage of SEM images stitched together to show an overall view of the fracture surface is shown in figure 6, and magnified views of fatigue regions in the indicated areas are shown in figures 7 and 8. Most fine fracture features were obliterated from post fracture oxidation and contact damage. However, radial marks showing fracture propagation initiating from corrosion pits at the interior surface of the tube were observed as shown in figure 7. At the location shown in figure 8, ratchet marks and faint curving crack arrest lines consistent with fatigue were

observed. The fatigue region had multiple origins at the interior surface that was roughened and pitted from corrosion.

Samples of material that had been scraped from the interior surface of the fracture tube were inserted in the SEM and analyzed using energy dispersive x-ray spectroscopy (EDS). The EDS spectra typically showed high peaks of carbon and iron with smaller peaks of oxygen, aluminum, chromium, and manganese. The elements and relative peak heights of the spectra obtained from the overall scan of the samples and individual particles were consistent with oxidized low alloy steel mixed with grease. Additionally, smaller cut particles of low alloy steel shavings that had smaller carbon and oxygen peaks in their spectra (consistent with metal shavings from the post-accident cutting process) and round particles of low alloy steel with a dendritic pattern on the surface (consistent with molten deposits that resolidified during the frame welding process) were also observed within the sample.

The intact vertical tubes attached to the left attachment foot shown in figure 1 were examined under an optical stereomicroscope, and no evidence of cracks were observed in the painted surfaces. Next, a transverse cut in the vertical plane was made through the center of the left attachment foot and two of the tubes attached to the upper side of the foot. A view of the cut surfaces on the aft piece is shown in figure 9. The interior surfaces of the tubes had dark areas that included longitudinally-oriented linear sliding contact features consistent with original manufacturing interspersed with areas of superficial orange oxides. The walls of both tubes appeared relatively uniform along the length of the cut and showed no evidence of thinning from corrosion.

Submitted by:

Matthew R. Fox, Ph.D.
Chief Technical Advisor, Materials Laboratory

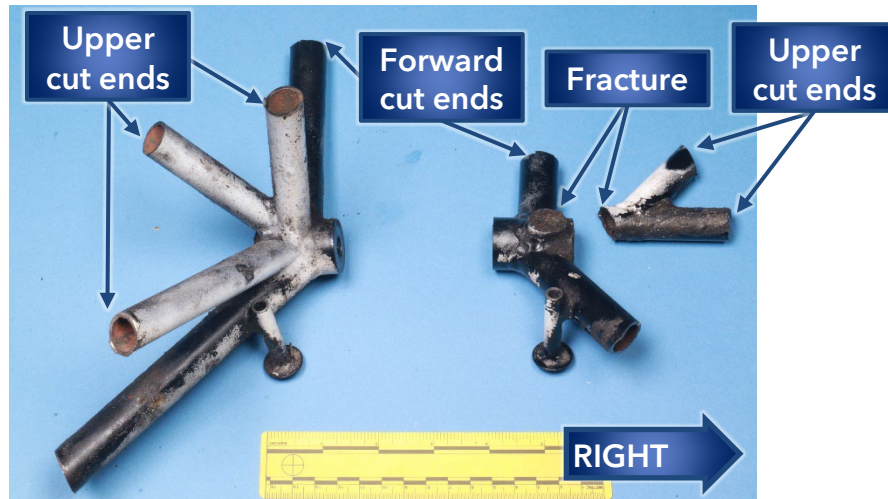


Figure 1. Overall view of the submitted engine mount pieces.



Figure 2. Closer views of the fracture surfaces as received.



Figure 3. Upper fracture surface after degreasing and ultrasonic cleaning. Brackets indicate multiple fatigue origins extending through thickness or to the fatigue boundary indicated with a dashed line. A circle indicates a damaged area with obliterated fracture features on the left side of the fracture.

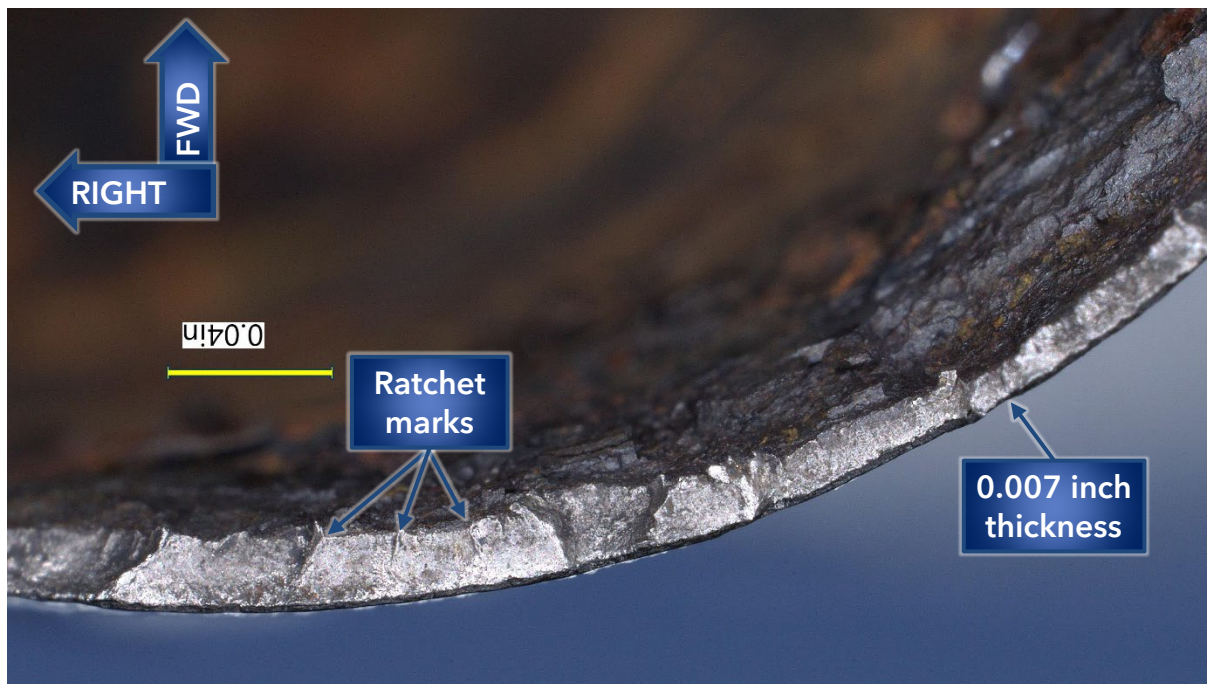


Figure 4. Portion of the fracture surface with flat fracture features, ratchet marks, and radial features consistent with fatigue with multiple origins at the inside diameter.



Figure 5. Area (indicated with an unlabeled arrow) where wall loss from corrosion extended nearly through the thickness.

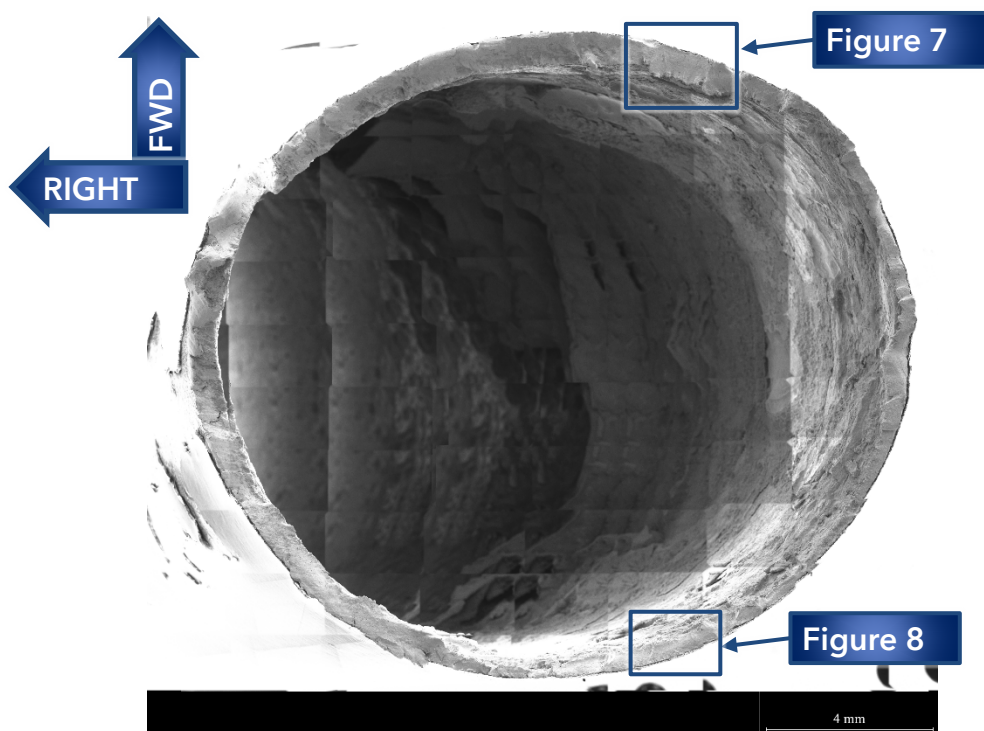


Figure 6. Montage of SEM images stitched together to show an overall view of the fracture surface.

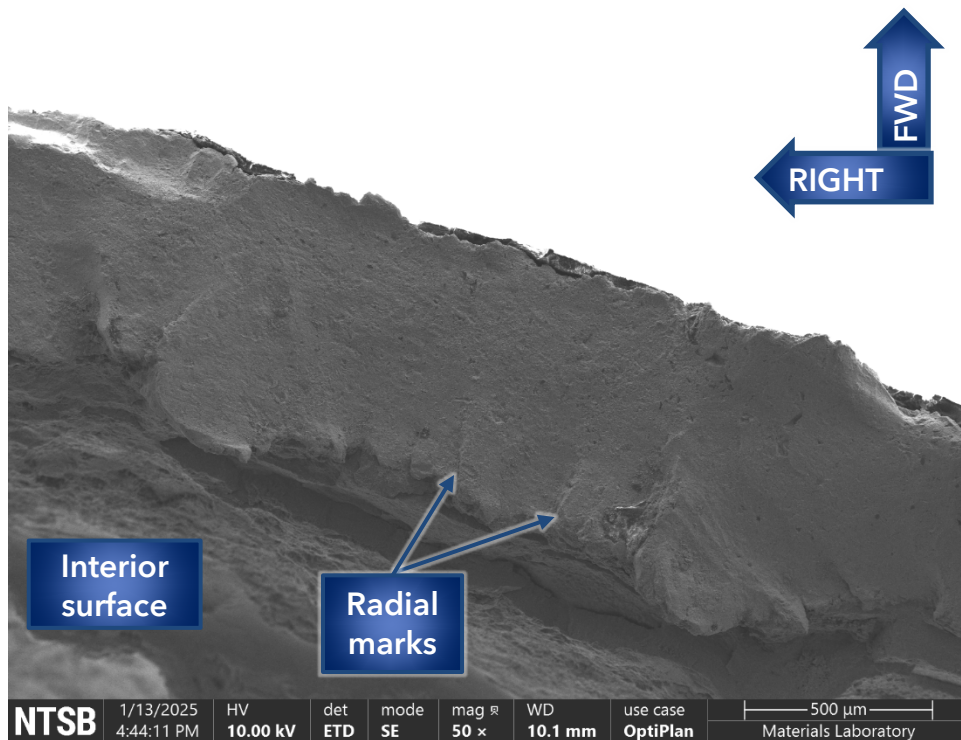


Figure 7. SEM image of flat features consistent with fatigue and post-fracture damage with radial features emanating from corrosion pits at the interior surface.

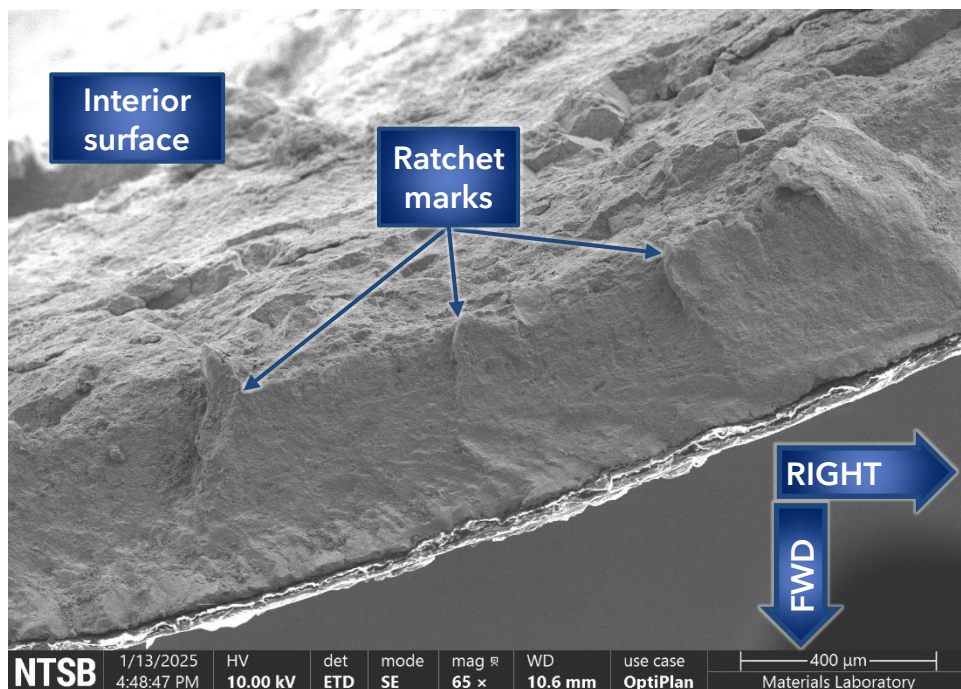


Figure 8. Ratchet marks and curving crack arrest lines consistent with fatigue with multiple origins at the corroded interior surface.



Figure 9. Aft side of the left foot and vertical tube members after cutting to expose the interior surfaces of the vertical tubes.