

NATIONAL TRANSPORTATION SAFETY BOARD

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



February 26, 2021

MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-003

1. ACCIDENT INFORMATION

Place : Salem, Oregon
Date : June 4, 2020
Vehicle : Piper PA-30, N8244Y
NTSB No. : WPR20LA252
Investigator : Tealeye Cornejo, AS-WPR

2. COMPONENTS EXAMINED

Remnants of a landing gear trunnion

3. DETAILS OF THE EXAMINATION

On June 4, 2020, at 1821 Pacific daylight time, a Piper PA-30 airplane was substantially damaged when it was involved in an accident at Salem, OR. The pilot and passenger were not injured. The pilot reported when he tried to lower the landing gear approaching the destination airport, they did not extend. They reported that after departure, the landing gear raised, and they heard a "clunk" noise. The nose and left landing gear doors were reported open, but the landing gear was not visible in the extended position. During a flyby at the Salem Airport, ground personnel reported that the main landing gear was partially extended, and the nose landing gear was not extended. Upon executing an emergency landing, the right main landing gear collapsed. A fractured trunnion was recovered and sent to the NTSB Materials Laboratory for additional examination.

Figures 1 through 3 show the trunnion fragments as received. Of most significance, was a fractured boss on the side—the mating faces of the fracture surface had been forced back and taped together prior to receipt by the NTSB Materials Laboratory. As illustrated in Figure 4, the mating fracture surfaces exhibited large areas of streaky and reflective features, consistent with post-fracture damage. Since the mating fracture surfaces had been in contact, it could not be determined if the post fracture damage was due conditions during or following the accident sequence, rubbing of the surfaces during shipping, or both.

The markings on the trunnion body stated, "2014 KAE 1B" and "PIPER 20750-5". There were additional markings on the rear of the trunnion, as shown in Figure 3. These stated "26-5148".

The boss, which extended orthogonally from the main trunnion body, had fractured approximately 2 inches from the end. The mating fracture surfaces are shown in Figure 5 from both sides. There were select areas of both fracture surfaces with relatively undamaged regions still exhibiting apparent fracture features. The inner mating fracture surface was less damaged than the outer one, and so it was sectioned 0.5 inches below the fracture surface to facilitate further examination.

Most of the undamaged portions of the fracture surfaces exhibited a rough, fibrous texture with a dull luster, as best demonstrated in the upper left of Figure 5a. There were two opposite facing areas that exhibited flatter and darker features. These features were located near the narrow neck-shaped area in the upper part of Figure 5b.

The sectioned fracture surface was examined using a scanning electron microscope (SEM). Most of the fracture surface exhibited features consistent with dimpled rupture as typified in Figures 6 and 7. These features were consistent with overstress fracture and corresponded with the dull, fibrous regions observed over the majority of the undamaged portions of the fracture surface.

The flatter, darker regions of the fracture surface exhibited distinctly different features, as demonstrated in Figure 8. These regions exhibited a stepped morphology with ridges. Closer examination found fatigue striations in these areas, as typified in Figure 9. These striations were consistent with having propagated from the outside surface inward.

Due to the post-fracture damage, only one crack initiation site was able to be observed, as shown in Figure 10. The surface near this feature exhibited fatigue striations consistent with crack propagation away from the location. Figure 11 shows a closer view of the fatigue crack initiation site. This figure shows striations emanating from a point along the surface. While the site exhibited an inward concave geometry, this feature was inconsistent with a corrosion pit or pore. Rather, the site was consistent with a geometrical inward shape.

Returning to a macroscopic view, the location of the fracture of the boss can be seen to have consisted of a boss to which a gusset or web that had been joined by welding. This was exemplified in the sectioned boss view of the trunnion in Figure 12. Viewing the mating section with the boss fracture, the geometry tapered to a narrowed neck shape, as shown in Figure 13. This tapered area correlated with the locations of the 2 opposite facing fatigue cracks.

The generalized location of the fatigue cracks, and their propagation directions, are demonstrated on the annotated figures in Figure 14. These figures show the relative size of the fatigue crack propagation depth, and the crack growth direction from the fatigue crack initiation sites. As the fracture surface was heavily damaged, and Figure 14b is a section below the actual fracture surface, the annotations in Figure 14a and 14b are for illustrative purposes and are not necessarily accurate delineations.

At this tapered area, the cross-sectional thickness was measured thin as 0.4 inches. In contrast, the welded gusset was 0.8 inches thick, and the boss exhibited a diameter (side to side) of 1.75 inches. This configuration would introduce a stress concentration at the locations of the fatigue cracking. Further, the presence of two opposite-facing fatigue cracks was consistent with reverse bending fatigue, suggestive of the gusset bending back and forth at the interface. Once these fatigue cracks had propagated far enough into the boss cross section, the remainder of the part fractured by overstress during the last landing.

The chemical composition of the sectioned trunnion was examined using x-ray fluorescence (XRF) and energy dispersive x-ray spectroscopy (EDS). From the data obtained using these techniques, the trunnion was found to be consistent with an AA 2014 aluminum alloy. The hardness was inspected per ASTM E18.¹ The hardness averaged 80 HRBW. The conductivity was inspected per ASTM E1004.² The conductivity averaged 36.9 % IACS. These data were consistent with a T6, or peak hardened, temper for this alloy per AMS 2568.³

The welded gusset however, exhibited a different chemical composition. The composition was consistent with an aluminum casting or welding alloy. The electrical conductivity was higher, averaging 42.9 % IACS. The hardness was softer than the Rockwell B scale, and was therefore not measured conclusively. The hardness of the boss material was found to decrease as it was probed closer to the weld. These data were consistent with the boss being locally softened due to the heat inputs from the welding process.

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

² ASTM E1004 – *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. ASTM International, West Conshohocken, PA

³ AMS 2658 – *Hardness and Conductivity Inspection of Wrought Aluminum Alloy Parts*. SAE International, Warrendale, PA

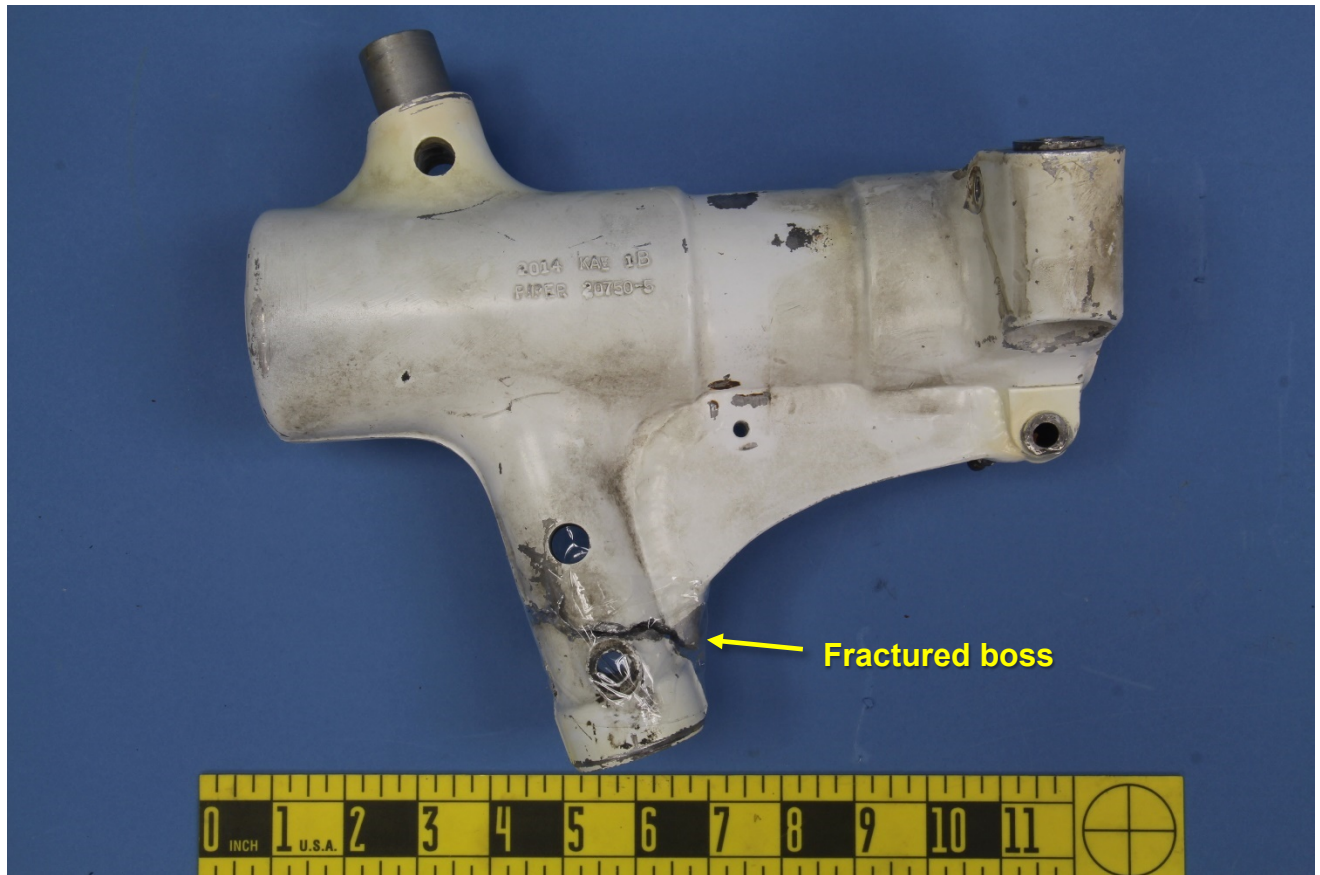


Figure 1 – Side view of the trunnion remnants, showing the fractured boss that was taped together, as received.



Figure 2 – View of the trunnion from the reverse side of Figure 1, as received.

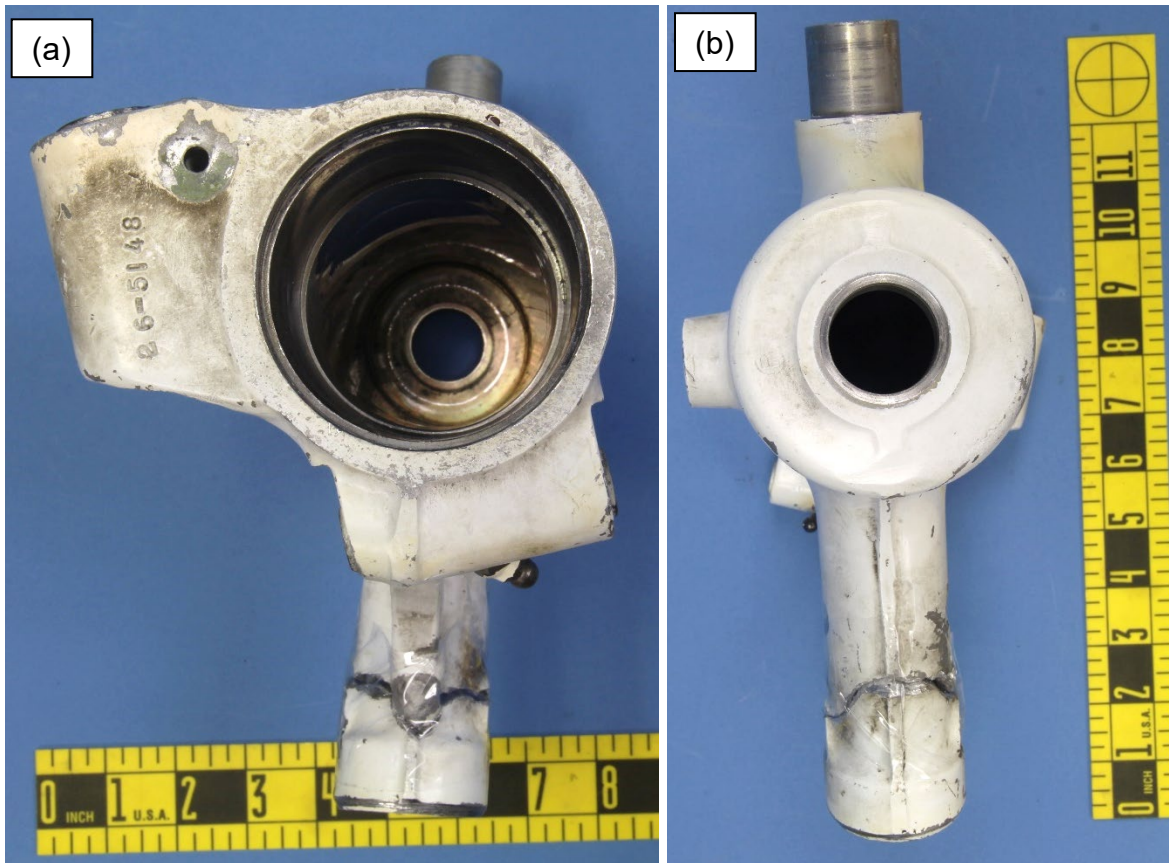


Figure 3 – View of the trunnion from the (a) piston side and (b) the opposite side.



Figure 4 – View of the two fracture surface of the fractured trunnion boss, after removal of tape and separation.

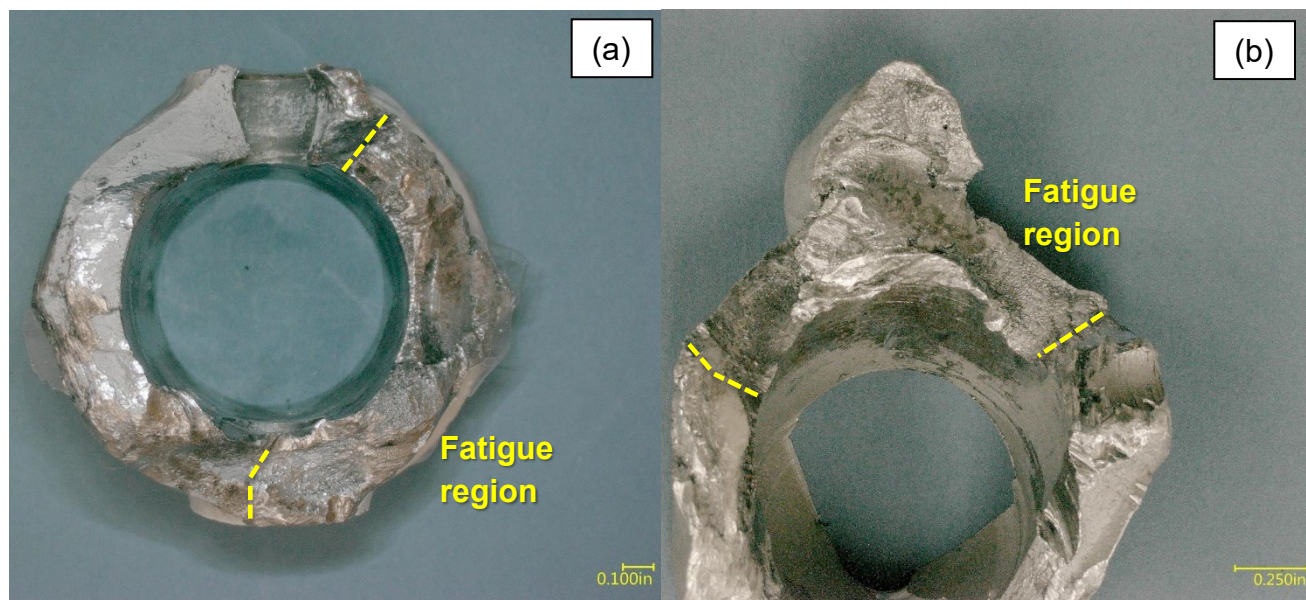


Figure 5 – Views of the (a) outer fracture surface of the boss and (b) the sectioned inner surface of the boss, annotated to show the progressive cracks on the surface.

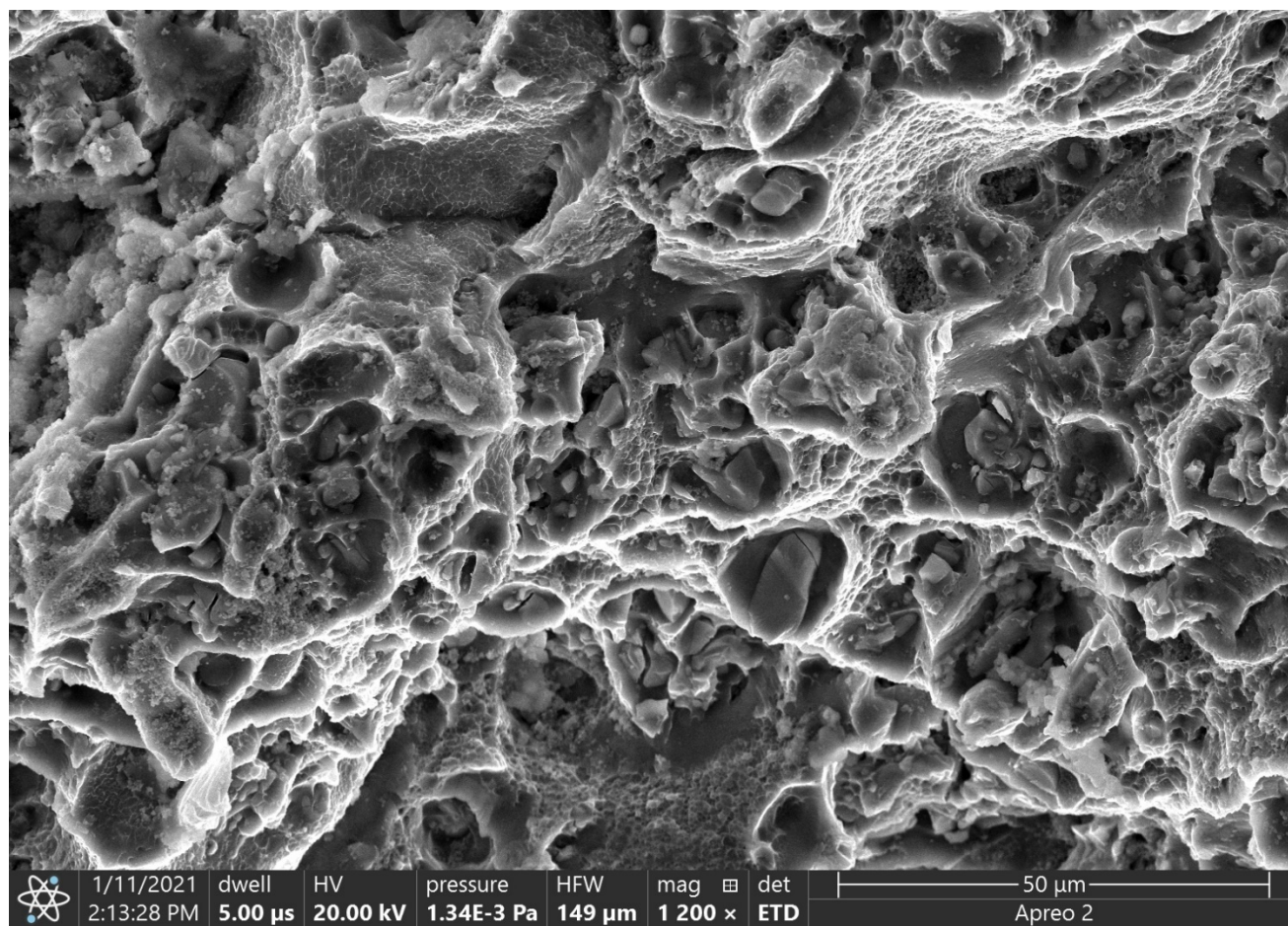


Figure 6 – Secondary electron (SE) micrograph of dimpled rupture on the inner boss fracture surface.

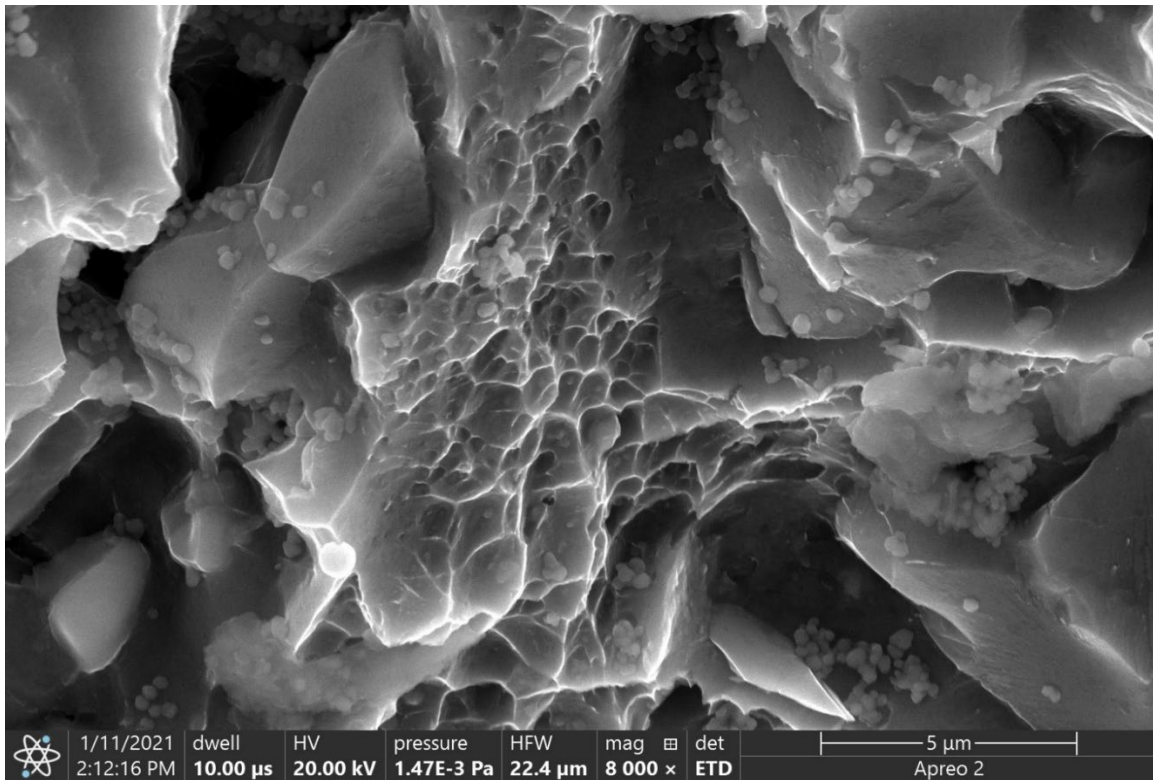


Figure 7 – SE micrograph of a closer view of dimpled rupture in Figure 6.

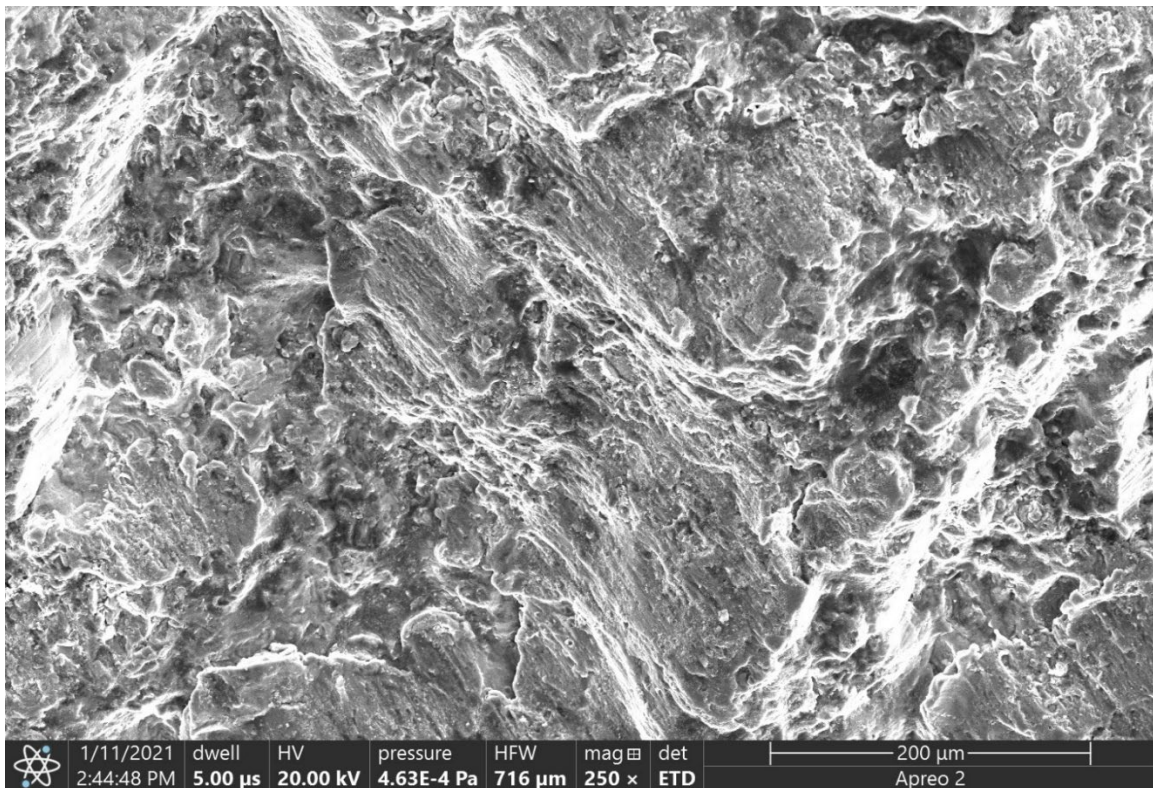


Figure 8 – SE micrograph of an area consistent with fatigue features on the inner fracture.

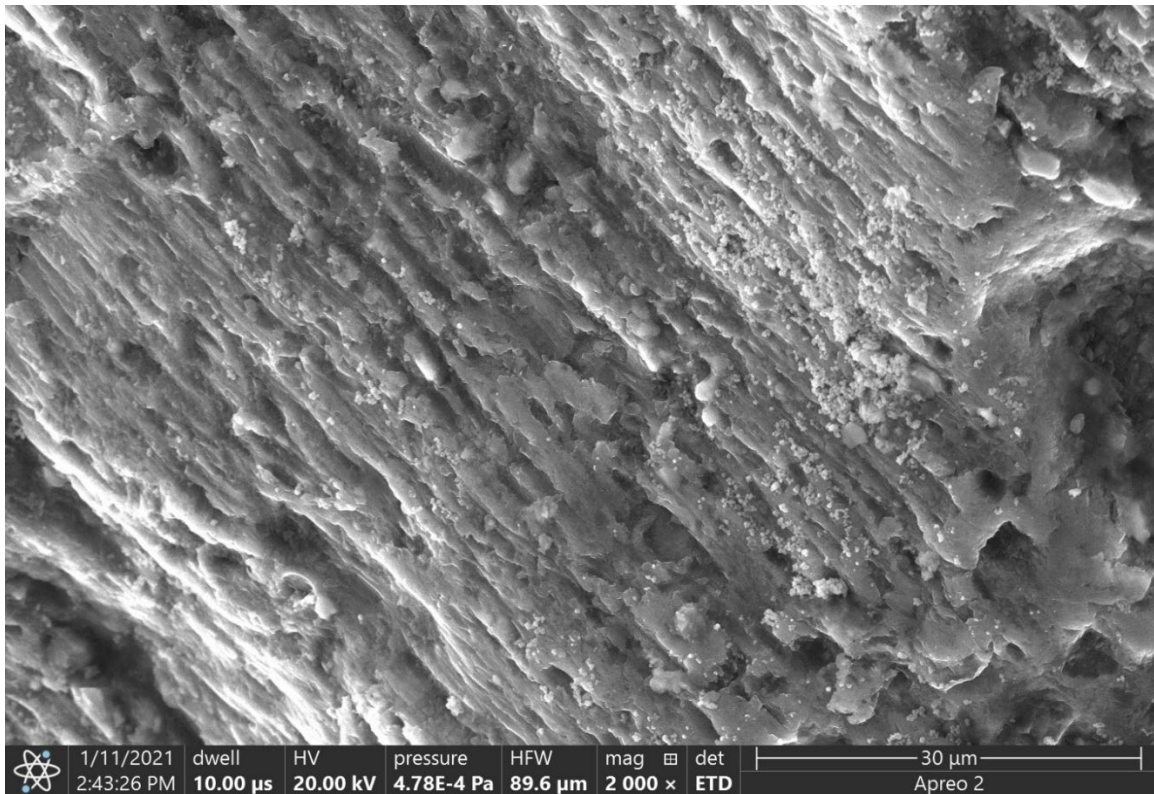


Figure 9 – SE micrograph of a closer view of fatigue striations from Figure 8.

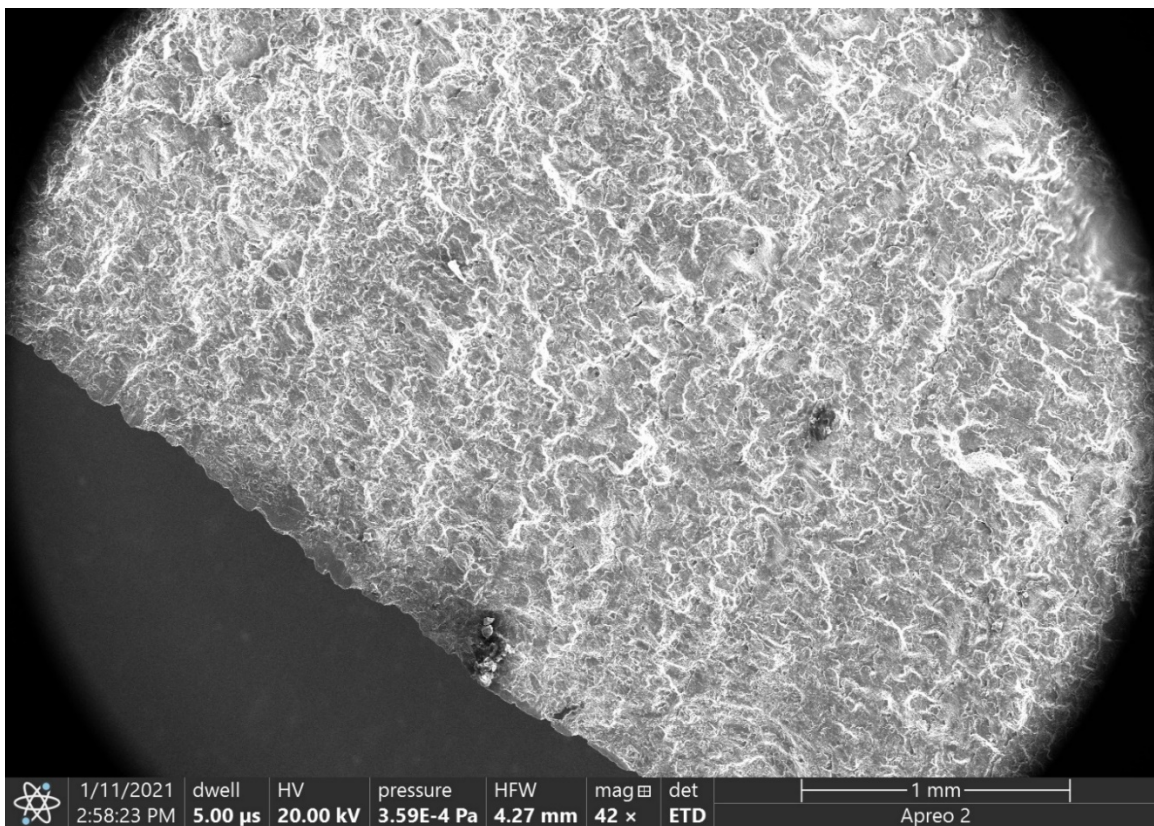


Figure 10 – View of a crack initiation site of one of the fatigue cracks.

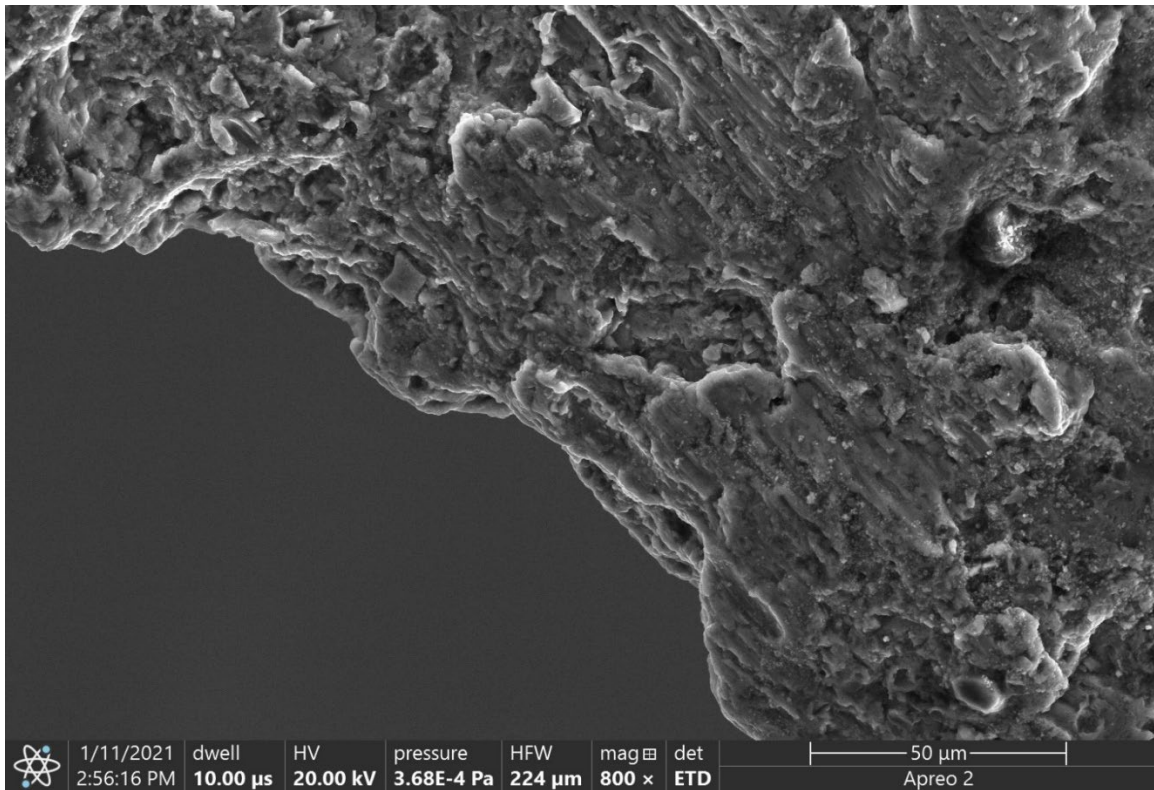


Figure 11 – SE micrograph showing a closer view of the crack initiation site of one of the fatigue cracks on the inner boss surface.



Figure 12 – View of the trunnion after sectioning of the inner fracture surface of the boss, showing the general cross-section dimensions of the joint.

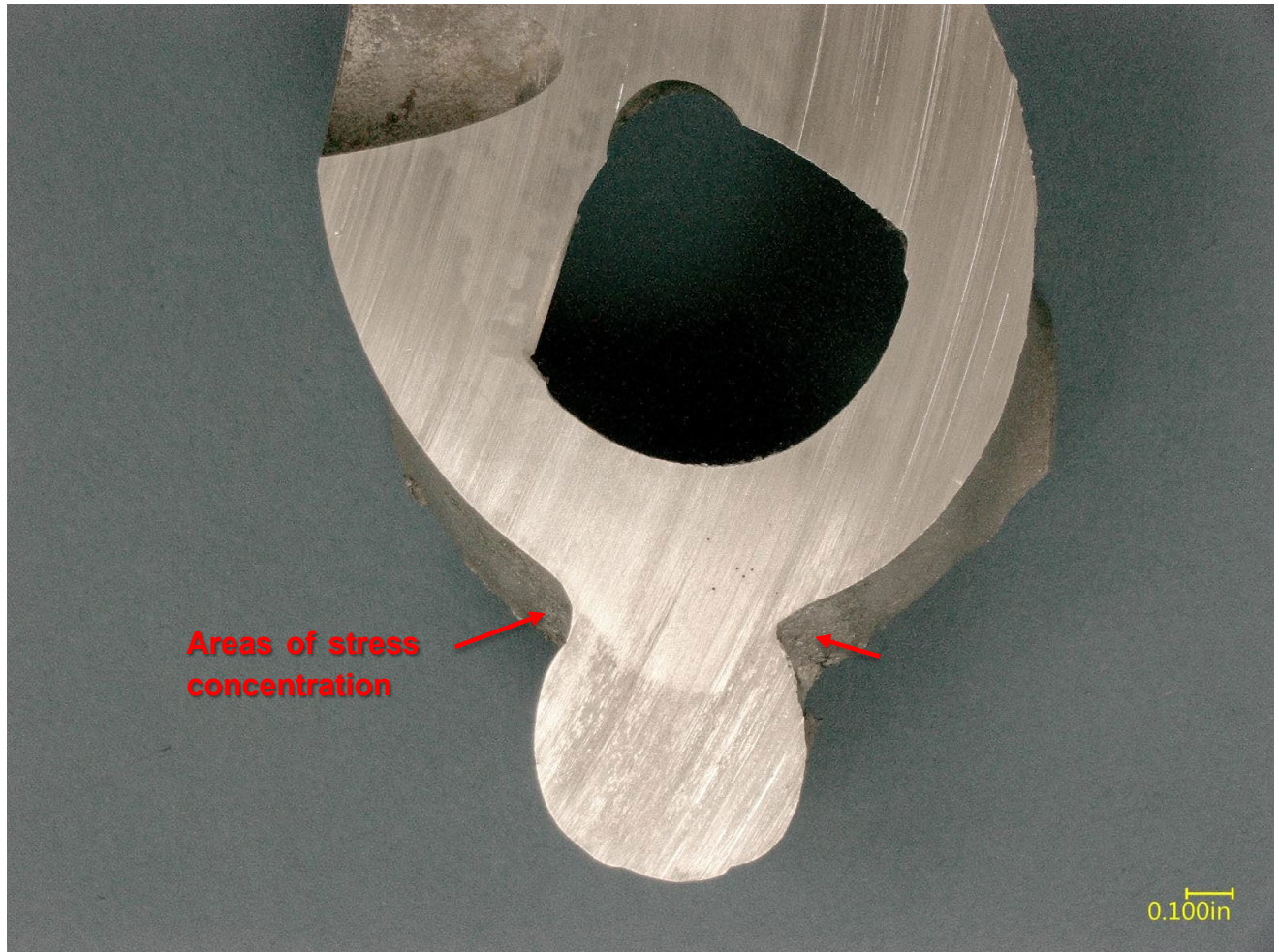


Figure 13 – Closer view of the sectioned inner boss piece, viewed from the cut surface, showing the two stress concentration regions at the weld joint.

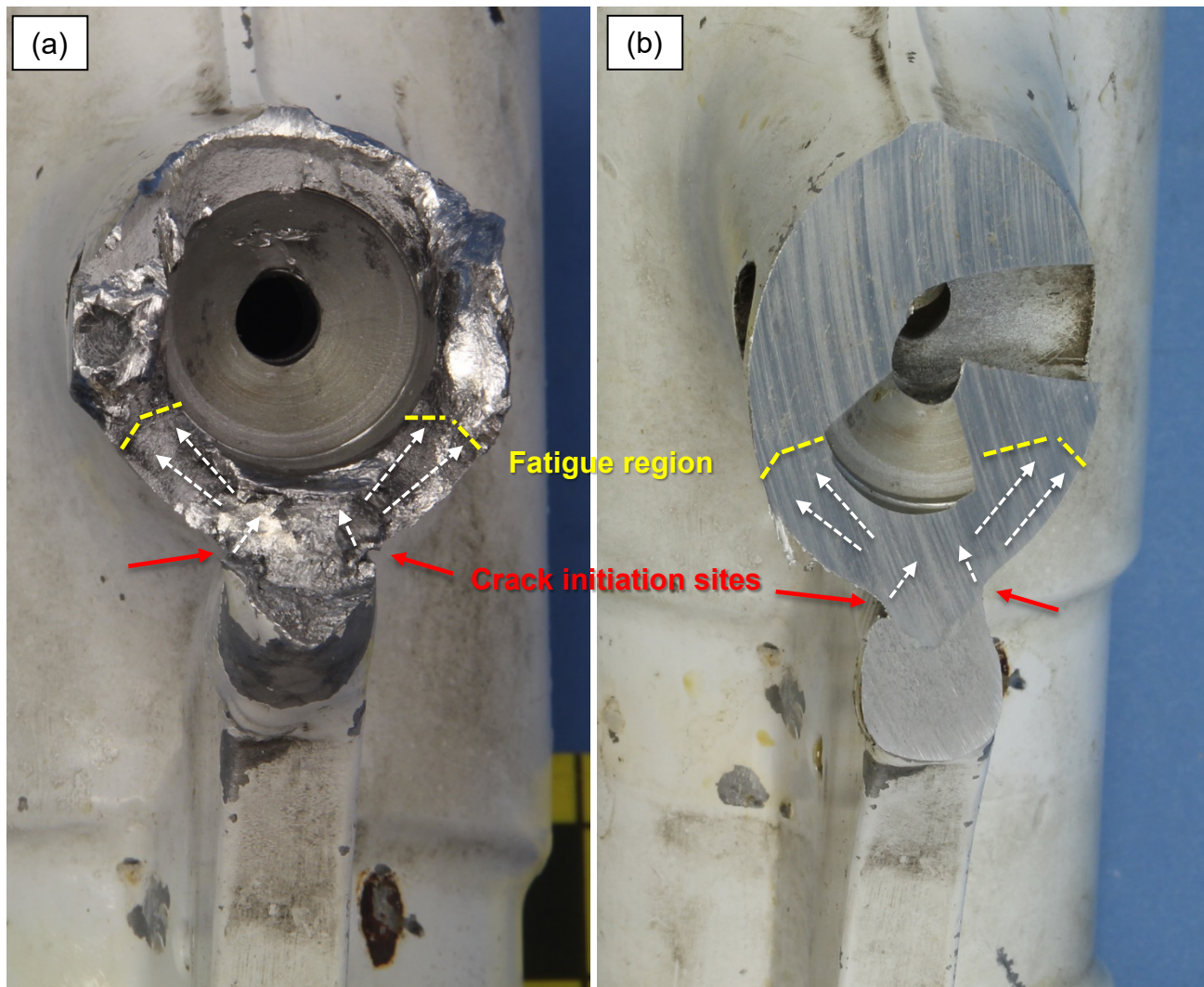


Figure 14 – Annotated views of (a) the boss fracture surface and (b) the sectioned boss surface, showing the relative locations of the extent of fatigue crack propagation (yellow dashed areas), the generalized crack growth direction (white dashed arrows) and the crack initiations sites (red arrows).