

NATIONAL TRANSPORTATION SAFETY BOARD

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

February 18, 2020



MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-007

1. ACCIDENT INFORMATION

Place : Dardanelle, California
Date : August 25, 2018
Vehicle : Bell 212, N512TA
NTSB No. : WPR18LA242
Investigator : Fabian Salazar, AS-WPR

2. COMPONENTS EXAMINED

Remnants of a swashplate assembly
Remnants of a collective support
Collective lever arms
Remnants of bearing liners and races
Trunnion
Remnants of an attachment bolt and spacer

3. DETAILS OF THE EXAMINATION

On August 25, 2018, about 1600 Pacific daylight time, a Bell 212 helicopter impacted terrain about one half-mile north of Dardanelle, CA. The airline transport pilot received serious injuries. The helicopter sustained substantial damage to the top of the fuselage, the main rotor blades and the tail rotor gearbox. The pilot of a nearby second helicopter reported that the accident pilot had requested to return to a nearby landing area due to an unspecified problem. The observing pilot stated that the accident pilot reported a problem that went away, after which he observed the accident helicopter in a 40° nose-down attitude. The helicopter then leveled and turned 360° while descending into terrain. The helicopter's main rotor blades struck terrain and the helicopter rolled over, coming to rest on its left side. Several components from the wreckage were recovered and sent the NTSB Materials Laboratory for further examination.

Figure 1 shows the components from the swashplate and support assembly, as received. Of note were the fractured clevises of the collective support, still attached to the gimble ring assembly in the swashplate assembly, along with a fractured bearing liner and ring.

Figures 2 through 4 show the swashplate support assembly from three different angles, as received. In general, the outer housing and surfaces of the swashplate were intact and relatively undamaged. Of note were a separated trunnion, visible by a dark hole in Figure 3.

Figure 5 shows the interior surfaces of the swashplate assembly. This view shows two fractured clevises from the collective support, still attached to the gimble ring assembly. The gimble ring was able to be actuated up and down, as received. The opposite view is shown in Figure 6—similar to Figure 5, this side of the gimble ring also exhibited two fractured clevis fragments from the support affixed to the gimble ring by an attachment bolt. On both sides, the clevises had fractured approximately 0.5 to 1 inches from the attachment bolt.

The bolts in the gimble ring were disassembled and the clevis fragments were removed from the swashplate assembly. Figures 7 and 8 show the inner faces of the swashplate housing after removal of the clevis fragments. On both sides, areas with smeared metal were observed. Each of these areas of smeared metal were approximately 1 inch long and 0.25 inches in width. The shapes of the smeared metal were consistent with impact marks from collision with an adjacent metallic part.

One of the bearing liners holding the attachment bolt of the fractured clevises had fractured on the inner surface, as shown in Figure 7. The bearing liner on the opposite side had fractured in several locations, on the inside and outside surfaces as shown in Figures 8 and 9. This bearing liner exhibited fractures in radial and circumferential directions.

Figures 10 through 12 show the collective support from four different faces, as received. The support exhibited the following markings: ASI-4011-404-125 REV F BT4-060 FAA-PMA IL909. Other markings were present on the part, but they had been disfigured with X-marks, consistent with vibroetched markings.

The most notable features on the support were the fractured clevises of the attachment yokes. Figure 13 shows the fracture faces of these clevises and the slot that was adjacent to the gimble ring. As shown in Figure 14, the slots exhibited some wear on the outer edges. There was little visible wear in the middle of the slots.

Figure 14 shows the forward side attachment slot of the collective support and fracture faces of the location. The removed clevis fragments from the swashplate were matched with this portion of the support—they are collectively illustrated in reconstructed positions in Figures 15 and 16. These clevis fragments were labeled 1 and 2 for the purposes of this report.

The fracture faces of the fragments did not completely match up with the fracture faces on the support. There were indications of necking and tearing adjacent to the fracture faces, consistent with local plastic deformation. The fracture faces also exhibited batter

and smearing. These features were consistent with post-fracture impact damage between the fragments and the support.

Figure 17 shows the aft side attachment slot of the collective support and gimble ring slot. The damage and wear patterns on this portion of the support were similar to the fractured slot on the forward side. The removed clevis fragments from the swashplate were matched with this portion of the support, and they are illustrated in reconstructed positions in Figures 18 and 19. These clevis fragments were labeled 3 and 4 for the purposes of this report.

Similar to the forward side, the aft support fracture reconstruction found features consistent with local plastic deformation, such as necking and tearing. In addition, the fracture faces were orientated away from the direction parallel to the support. This misorientation is shown in Figure 18. These features were consistent with a bending component to the fracture of the clevises 3 and 4. Like the forward side, the aft side fracture surfaces exhibited features consistent with post-fracture impact damage, such as smearing and batter.

Figure 20 shows the inward and outward faces of clevis fragment 1. The fragment exhibited a slant-angled fracture surface located between 0.12 and 0.25 inches from the shoulder of the attachment piece. Figure 21 shows the fracture surface of this clevis fragment. The fragment was bent on the right side of Figure 21, consistent with a twisting moment on that side. The left side of the fracture surface had been significantly damaged by post-fracture smearing.

Overall, the clevis 1 fracture surface exhibited a general rough texture, with a dull luster. There were no indications of features consistent with multiple fracture modes or corrosion. This fracture surface was cleaned with acetone and examined using a scanning electron microscope (SEM). The undamaged fracture features on the clevis 1 fracture surface were relatively uniform. Figure 22 shows a typical area of the clevis 1 fracture surface, which exhibited dimple rupture and radiating cleavage features, consistent with overstress fracture of the part. Figure 23 shows a closer view of the dimple rupture features. A typical area in the left side of Figure 21 is illustrated in Figure 24. This figure shows streaks and smoothing, consistent with smearing from post-fracture damage.

Figure 25 shows the inward and outward faces of clevis fragment 2. The fragment exhibited a curved fracture surface located with a pointed protrusion on one side. Figure 26 shows the fracture surface of this clevis fragment. While not as pronounced as clevis one, there were indications of twisting at the clevis 2 fracture. The left side of the fracture surface had been significantly damaged by post-fracture smearing. Examination of the fracture surface of clevis 2 revealed features consistent with overstress fracture. This is illustrated in Figure 27, showing dimple rupture.

Figure 28 shows the inward and outward faces of clevis fragment 3. The fracture surface of the fragment exhibited two curves; therefore, there were three protrusions on the fracture surface. Figure 29 shows the fracture surface of this clevis fragment. The left

side of the fracture surface showed localized necking as well as severe batter on the inner and outer edges of the fragment. Examination of the fracture surface of clevis 3 revealed features consistent with overstress fracture. This is illustrated in Figure 30, showing dimple rupture.

Figure 31 shows the inward and outward faces of clevis fragment 4. The fragment exhibited an angled fracture surface. Figure 32 shows the fracture surface of this clevis fragment. This fracture surface exhibited batter and smearing in multiple locations, consistent with post-fracture impact. Examination of the undamaged portions of the clevis 4 fracture surface revealed features consistent with overstress fracture. This is illustrated in Figure 33, showing dimple rupture. The damaged areas, as typified in Figure 34, exhibited streaks and smoothing. These features were consistent with smearing from post-fracture damage.

The chemical composition of the support near the fracture surfaces was inspected using energy dispersive x-ray spectroscopy (EDS) and x-ray fluorescence (XRF). The composition was consistent with high-Si aluminum casting alloy, such as A391 or A392. The electrical conductivity was inspected per ASTM E1004.¹ The conductivity was measured as 38.6 %IACS. The hardness was inspected per ASTM E18.² The hardness averaged 54 HRBW. These data were consistent with those typical of cast Si-aluminum alloys.

A portion of the clevis 3 fragment was cross-sectioned, mounted, polished and etched to examine the microstructure. Figures 35 and 36 show typical areas of the microstructure of the clevis fragment from the support, after etching with Keller's Reagent.³ The microstructure shows a general dendritic morphology, consistent with those typical of castings. The lighter regions were the aluminum rich areas of the microstructure, and the dark blue constituents were the silicon-rich interdendritic phases. The microstructure, conductivity, and hardness were consistent with those typical of high-Si aluminum casting alloys. The dimple rupture and radiating cleavage features on the fracture surfaces of the clevis fragments were consistent with those typically observed with overstress fractures in aluminum-silicon castings.

Figure 37 and 38 show the left and right collective arms, as received. The arms had been separated from the rest of the swashplate assembly before receipt by the Materials Laboratory. The markings on the right collective lever arm stated, "P/N = 21 2 010 4035, S/N = 883002426 Bell Helicopter." The markings on the left collective arm stated, "P/N = 2120104035, S/N = 883002354." There were some impact marks on the outer surfaces of the arms. Besides these small impact marks, there were no other indications of damage or deformation on these parts.

¹ ASTM E1004 – *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. ASTM International, West Conshohocken, PA

² ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

³ Keller's Reagent is a solution of 1% nitric acid, 1.5% hydrochloric acid, 3.5% hydrofluoric acid in distilled water.

Two bearing and liner assemblies were received separated from the swashplate assembly. As received, these parts were completely covered in grease. The grease had been thickly applied, and they did not exhibit any dark discoloration or foul odors. Figure 39 shows the bearing assemblies after degreasing and cleaning. This bearing assembly was generally intact. There was a fracture in one of the bearing races, as shown in Figure 39a and 39b. These fractured parts were completely contained inside the assembly.

Figure 40 and 41 shows the bearing other bearing liner and bearing race, after degreasing and cleaning. As shown in Figure 40, the outer housing of the bearing liner had fractured outward. This portion of the part exhibited plastic deformation and multiple fracture locations. These features were consistent with overstress in an outward direction.

The bearing race in Figures 40 and 41 was consistent with one that would have sat inside the bearing liner in Figure 40. This race exhibited two fracture surfaces, consistent with those of the liner. These fracture surfaces were examined using a SEM. The fracture surfaces exhibited dimple rupture, consistent with overstress fractures.

Figure 42 shows the spacer and attachment bolt, as received. As shown in Figure 43, the outer surface exhibited some impact marks, consistent with localized inward buckling at those locations. The attachment bolt is shown after disassembly in Figure 44. As shown in the figure, the bolt had bent approximately 2 inches below the bolt head.

Figure 45 shows the loose trunnion, viewed from both sides. The bottom of the trunnion (to the left in both figures) exhibited stamped markings. The markings stated, "SHAFER YD2414 204-011-451-1 MADE IN USA PAT." The trunnion exhibited longitudinal marks on the sides, consistent with sliding out of its retainer. There were no other indications of damage on the loose trunnion.

Erik M Mueller
Materials Research Engineer



Figure 1 – The components from the swashplate and sleeve assembly, as received.

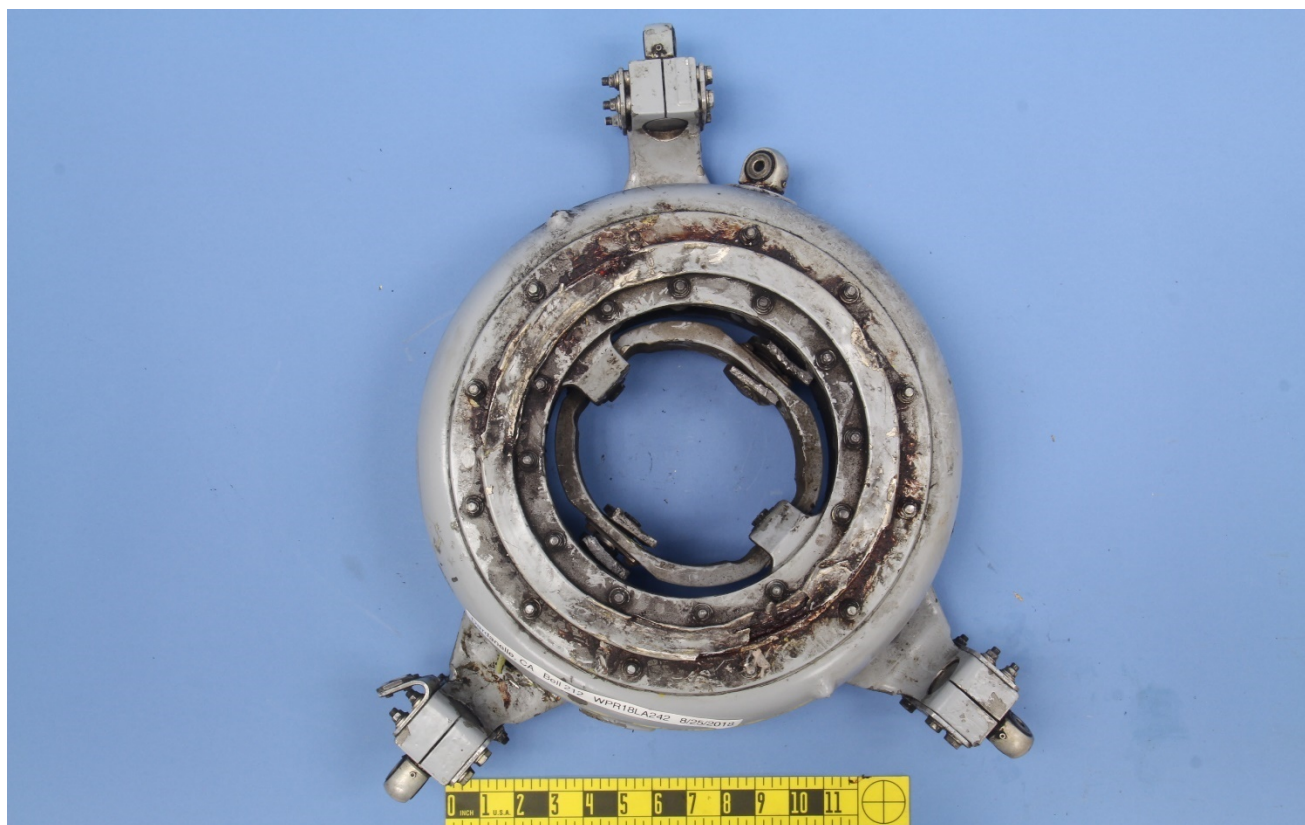


Figure 2 – The swashplate assembly, viewed from the upper face.

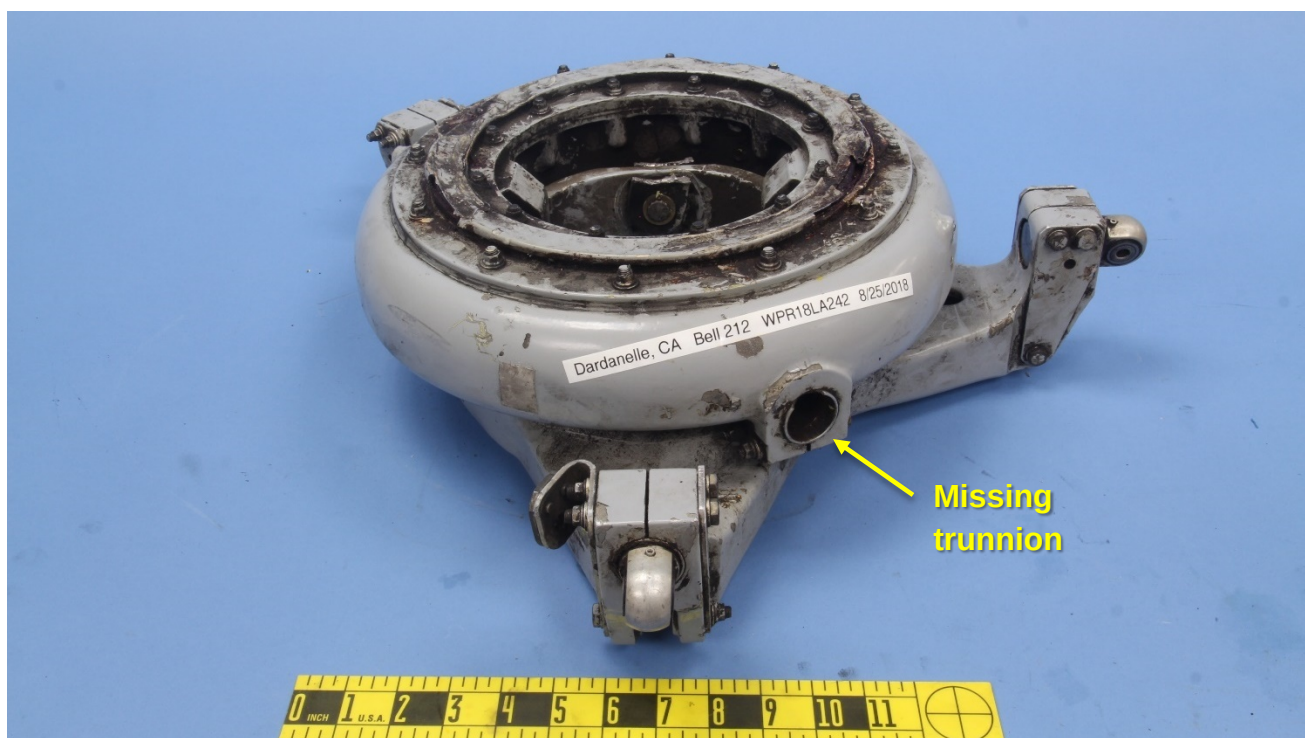


Figure 3 – The swashplate assembly, angled view from the side.



Figure 4 – Angled view of the swashplate assembly, rotated 180° from Figure 3.



Figure 5 – View of two of the fractured clevises from the collective support, attached to the swashplate assembly through the gimbal ring assembly, as received.



Figure 6 – View of two of the fractured clevises from the collective support, attached to the swashplate assembly through the gimbal ring assembly, as received.

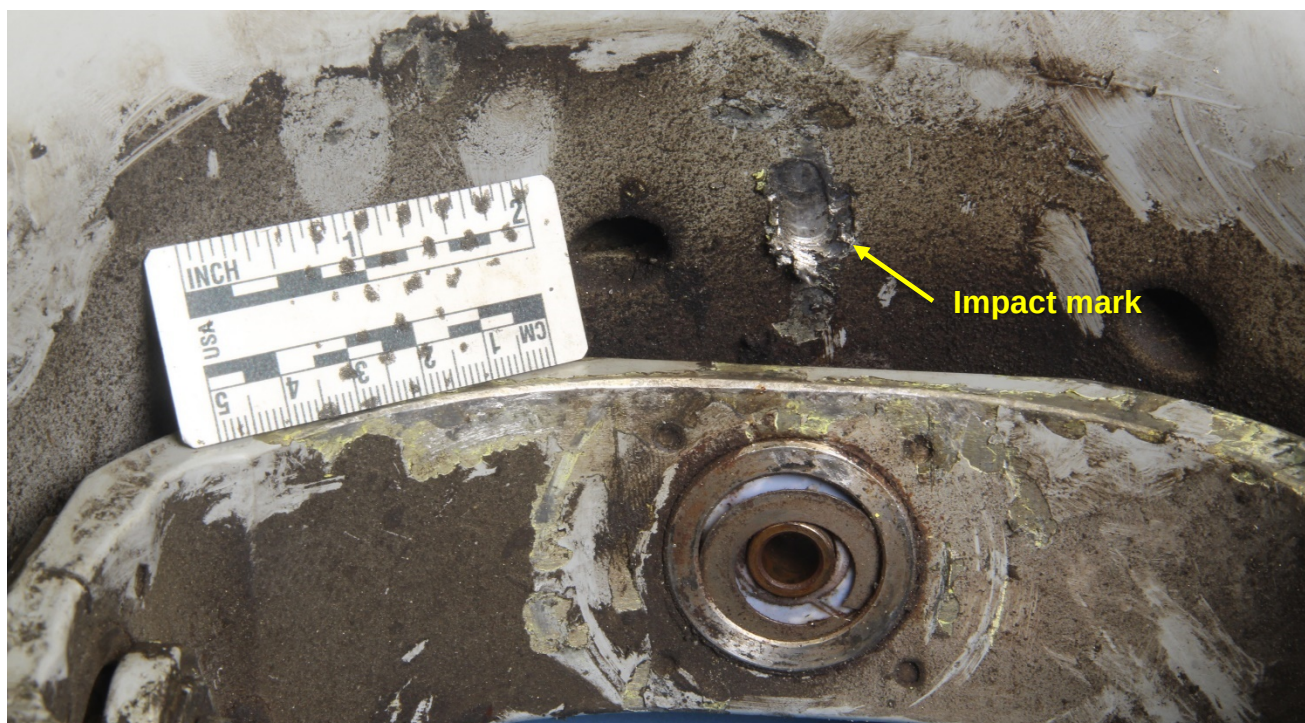


Figure 7 – View of the area in Figure 6, after removal of the bolt and clevises. With the gimble ring pushed down, impact marks were present on the inner surface of the swashplate housing.



Figure 8 – View of the area in Figure 5, after removal of the bolt and clevises. With the gimble ring pushed down, impact marks were present on the inner surface of the swashplate housing.



Figure 9 – View of the fractured bearing and liner on the gimble ring opposite Figure 8.



Figure 10 – The collective support, viewed from the right side, showing fractured attachment clevis remnants and an impact mark.



Figure 11 – The collective support, viewed from the left side.



Figure 12 – The support in Figure 10, shown from (a) the forward side and (b) the aft side.



Figure 13 – A topside view of the support, showing the fractured attachment clevises.



Figure 14 – The forward gimble ring seat of the support, which fractured on the attachment clevis.

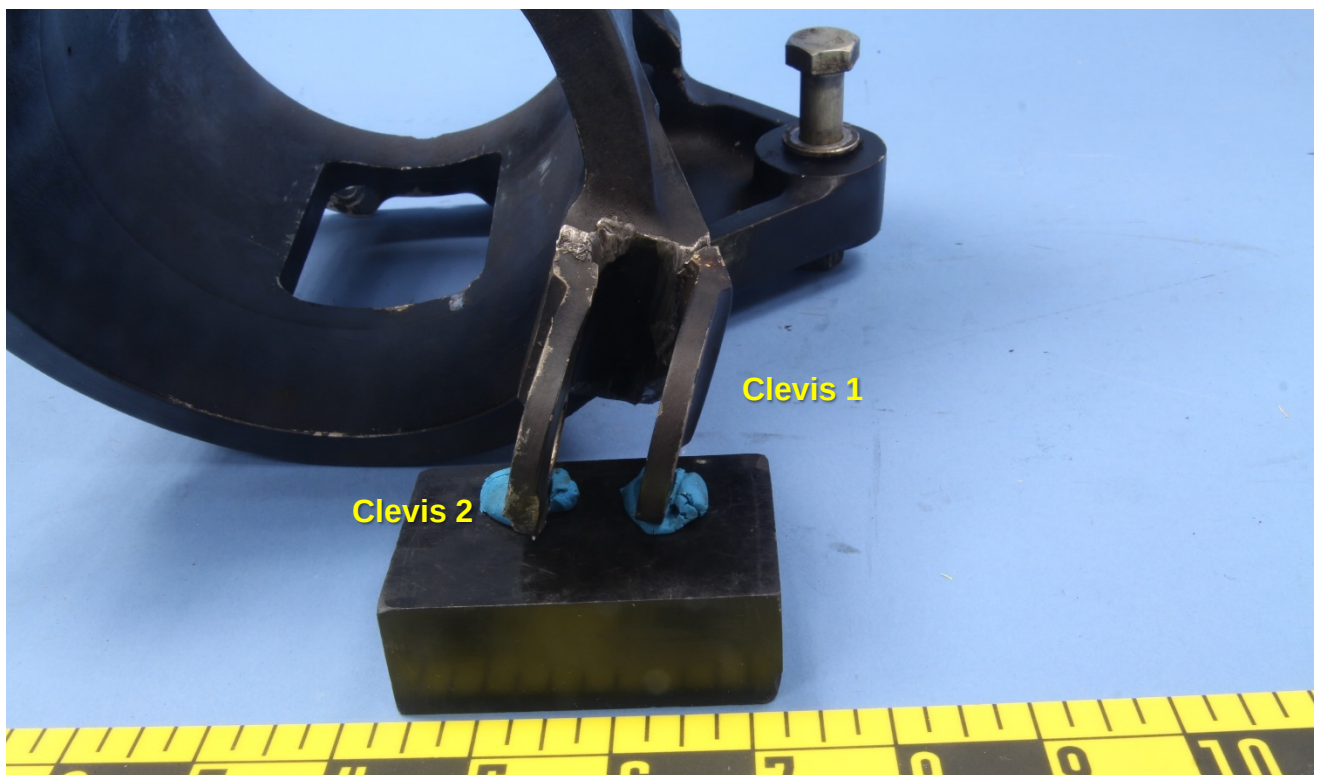


Figure 15 – The forward fractured clevises of the support, staged to show their positions at fracture. The clevis remnants were labeled "1" and "2" for the purposes of this report.

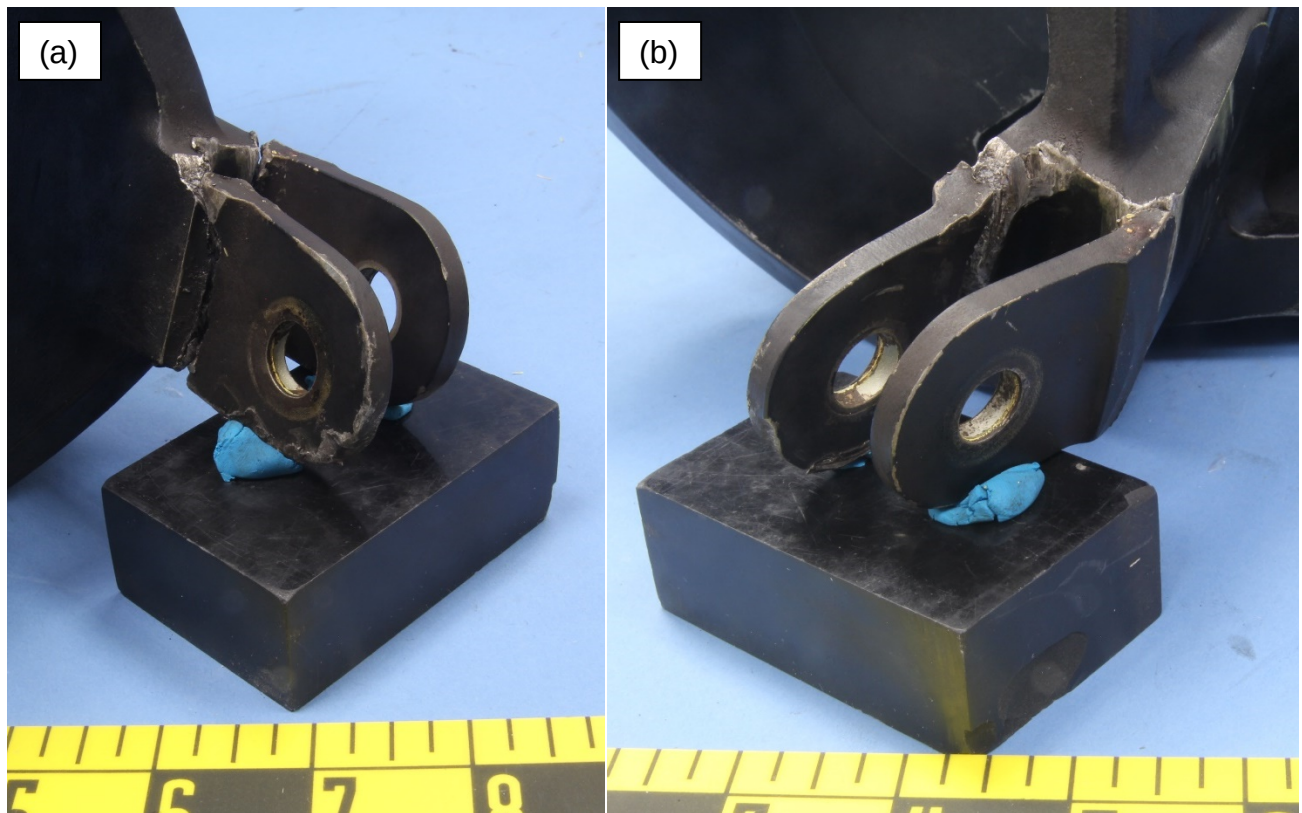


Figure 16 – The repositioned clevises 1 and 2 viewed from (a) the aft side and (b) the forward side.



Figure 17 – The aft gimble ring seat of the support, which fractured on the attachment clevis.

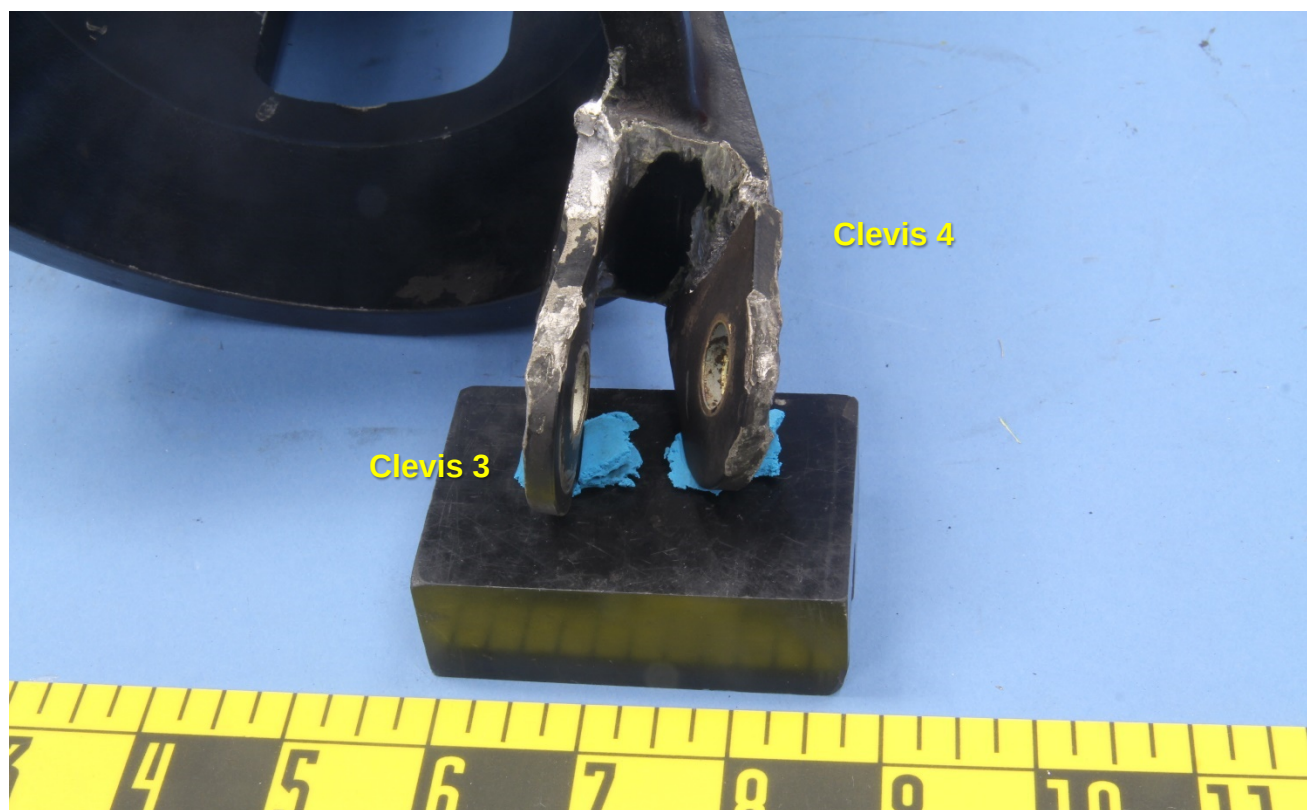


Figure 18 – The aft fractured clevises of the support, staged to show their positions at fracture. The clevis remnants were labeled “3” and “4” for the purposes of this report.

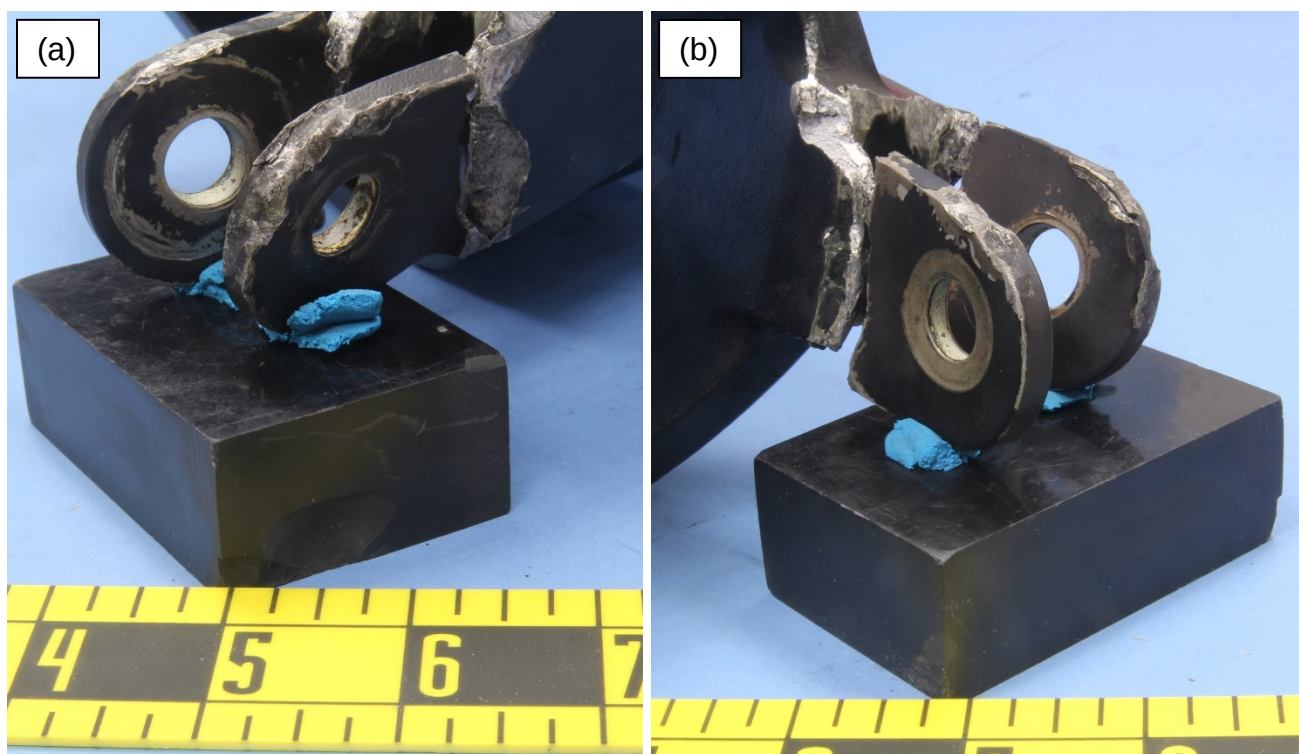


Figure 19 – The repositioned clevises 3 and 4 viewed from (a) the aft side and (b) the forward side.

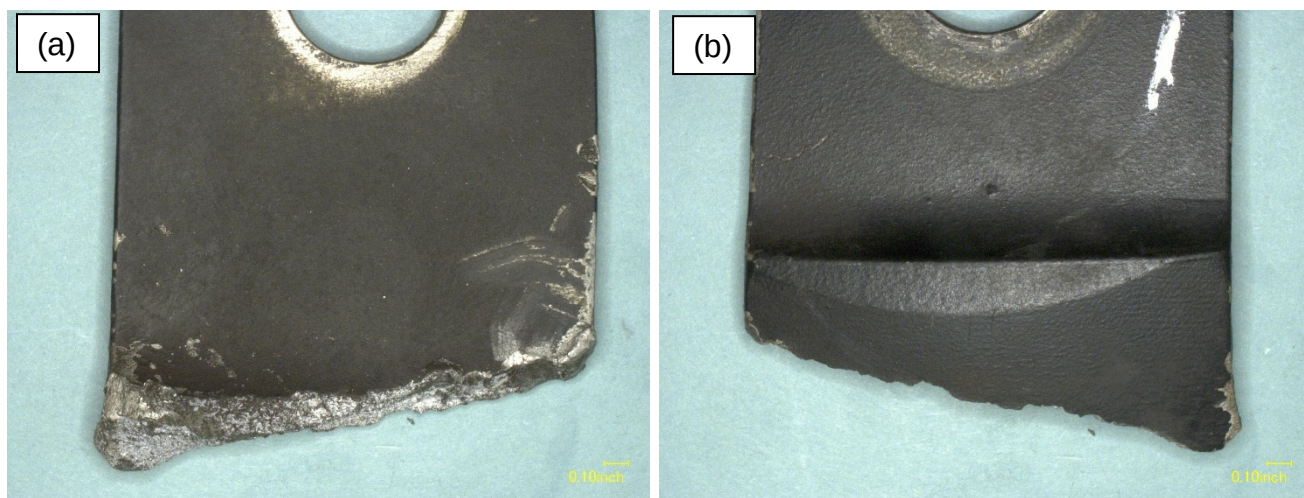


Figure 20 – The (a) inward and (b) outward-facing surfaces of the fractured support clevis 1.



Figure 21 – View of the fracture surface of the fractured support clevis 1.

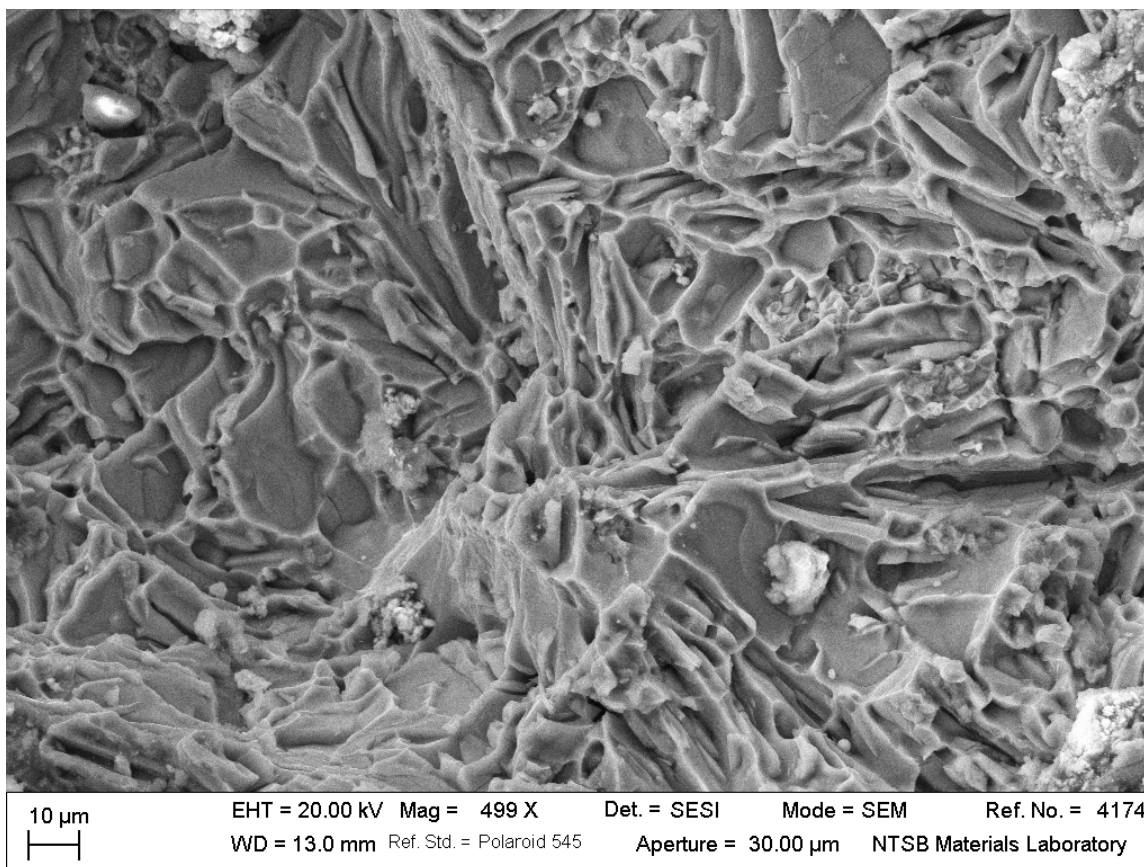


Figure 22 – Secondary electron (SE) micrograph of a typical area of the fracture surface of clevis 1.

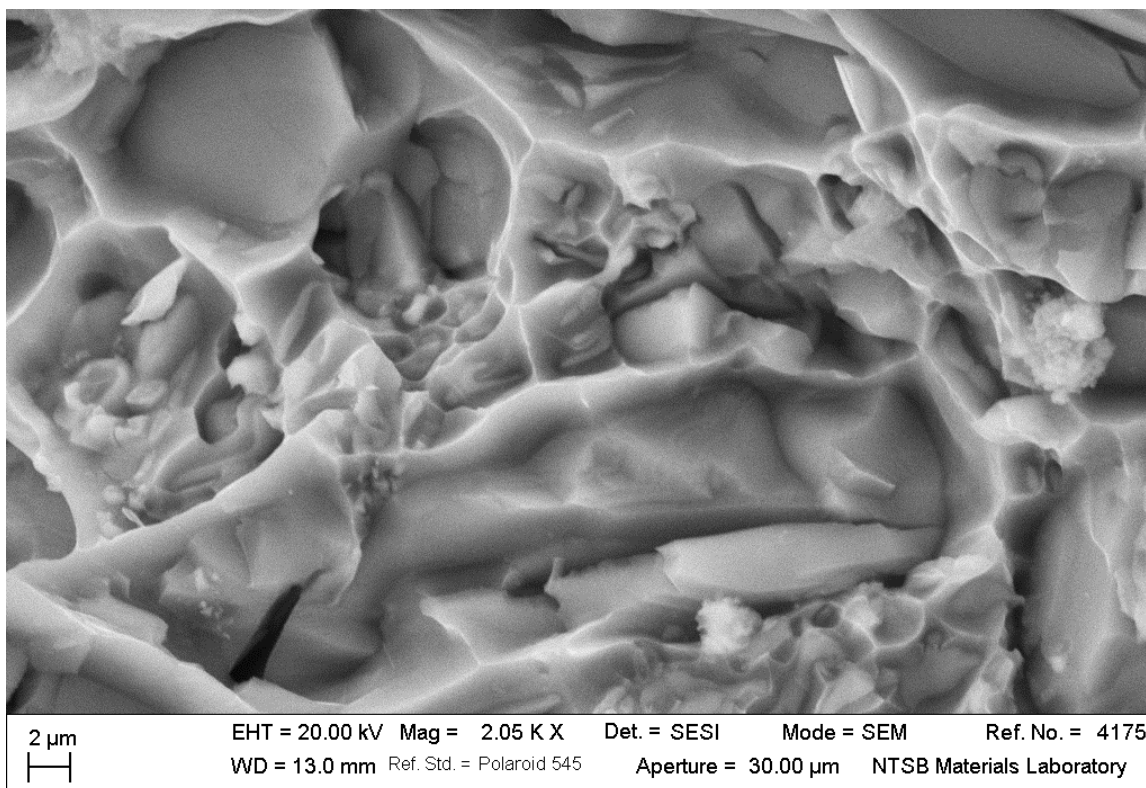


Figure 23 – SE micrograph of dimple rupture on the clevis 1 fracture surface.

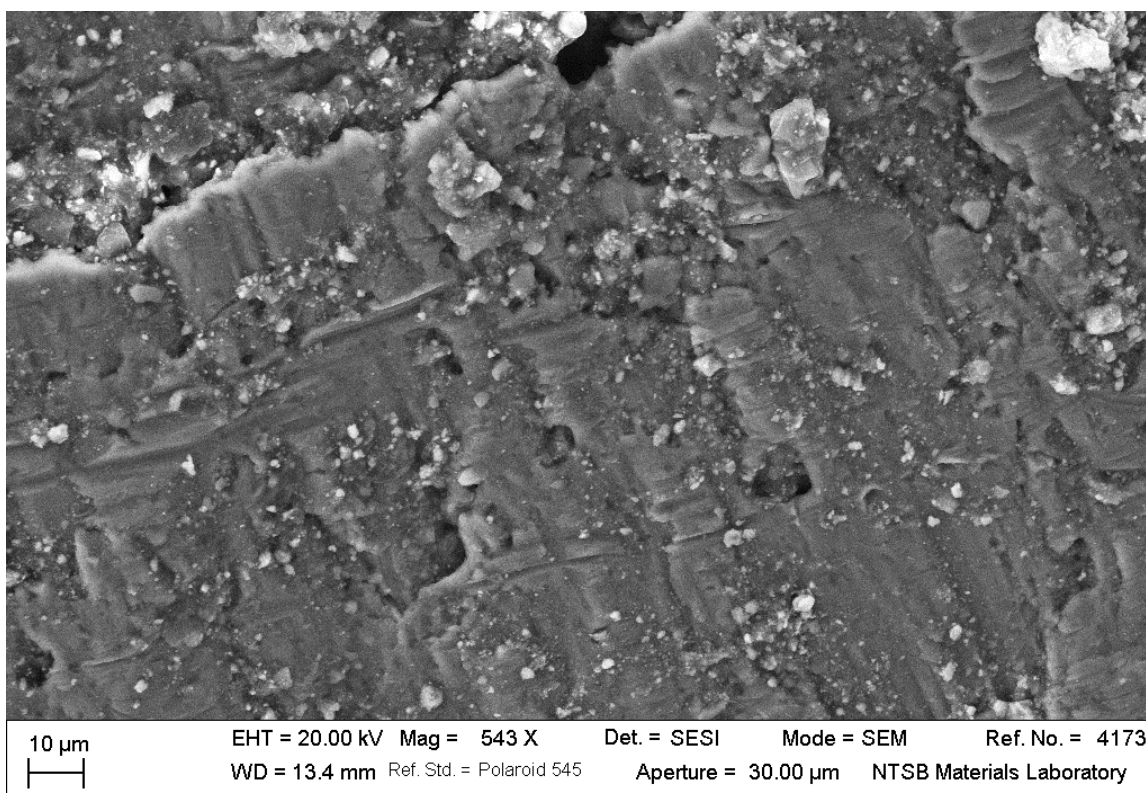


Figure 24 – SE micrograph of typical area of smearing on the clevis 1 fracture surface.

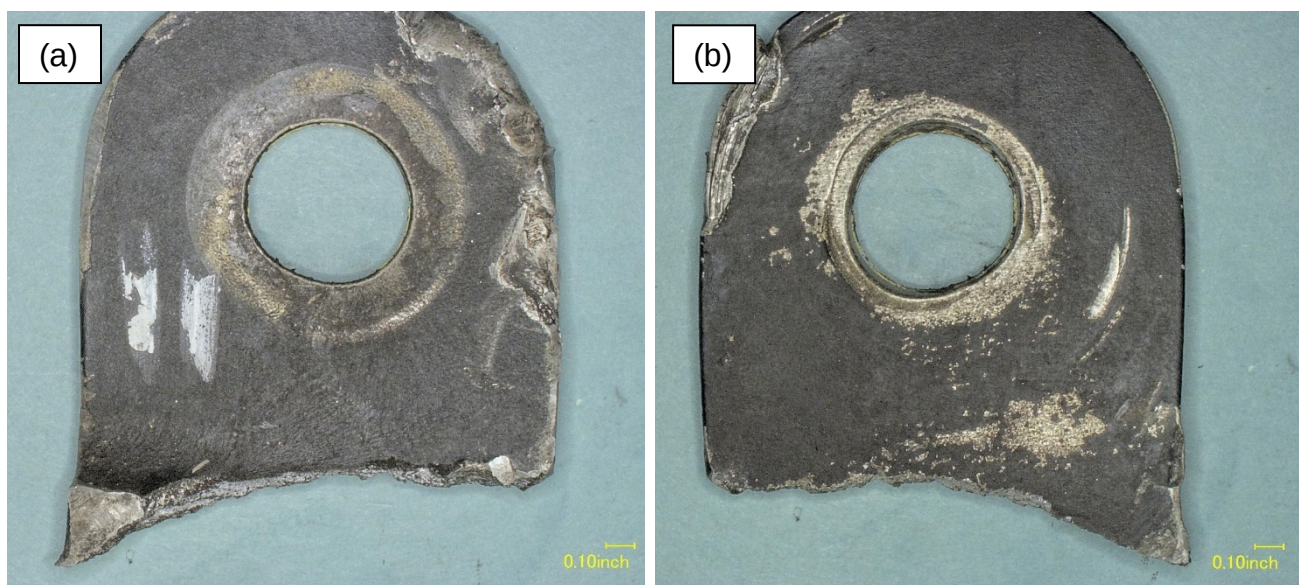


Figure 25 – The (a) inward and (b) outward-facing surfaces of the fractured support clevis 2.



Figure 26 – View of the fracture surface of the fractured support clevis 2.

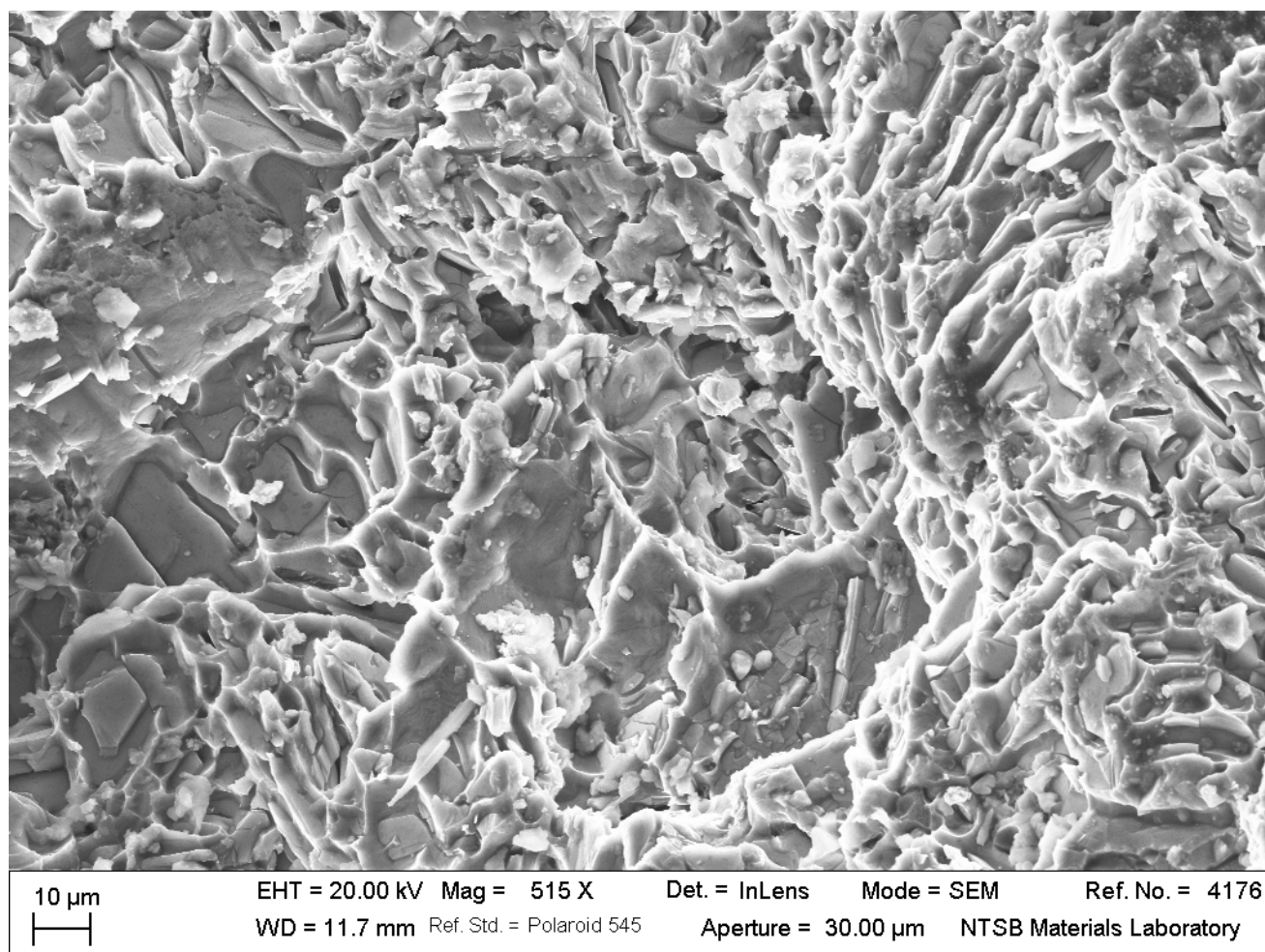


Figure 27 – SE micrograph of a typical area of the fracture surface of clevis 2, showing dimple rupture.

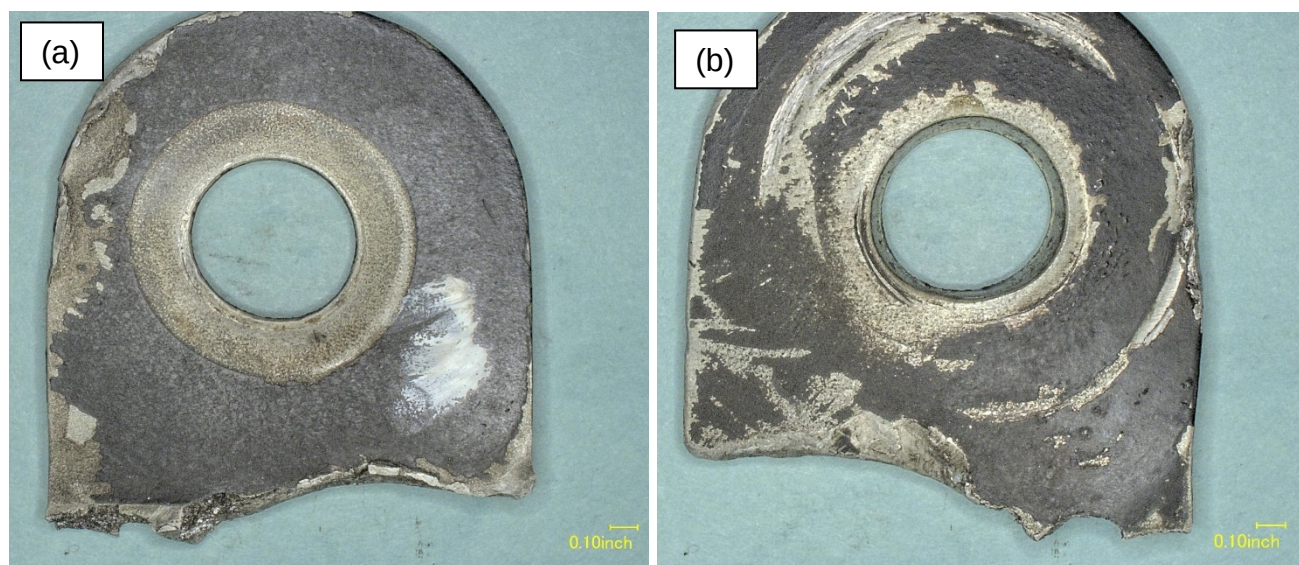


Figure 28 – The (a) inward and (b) outward-facing surfaces of the fractured support clevis 3.



Figure 29 – View of the fracture surface of the fractured support clevis 3.

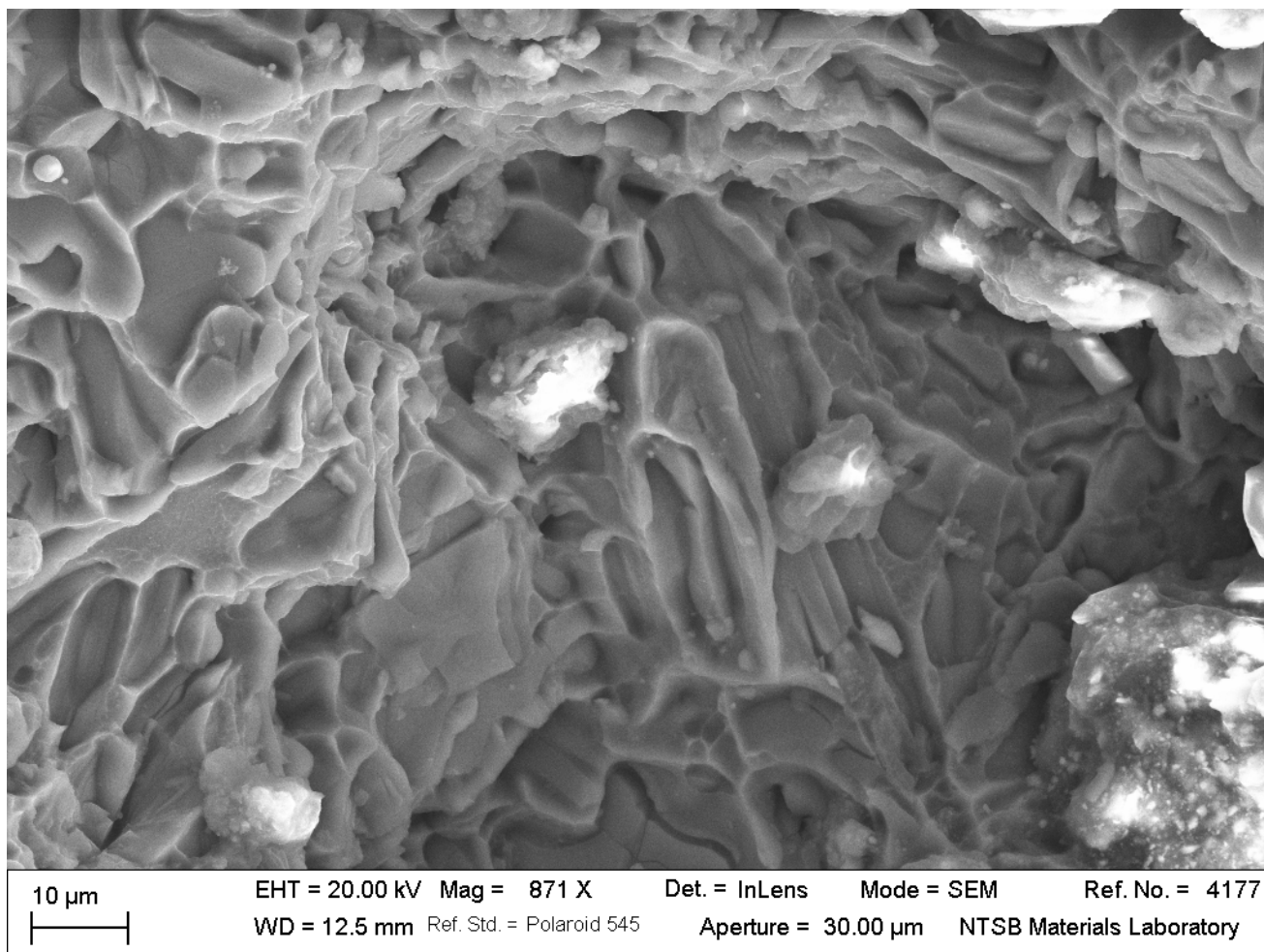


Figure 30 – SE micrograph of a typical area of the fracture surface of clevis 3, showing dimple rupture, with some non-conductive material on the surface.

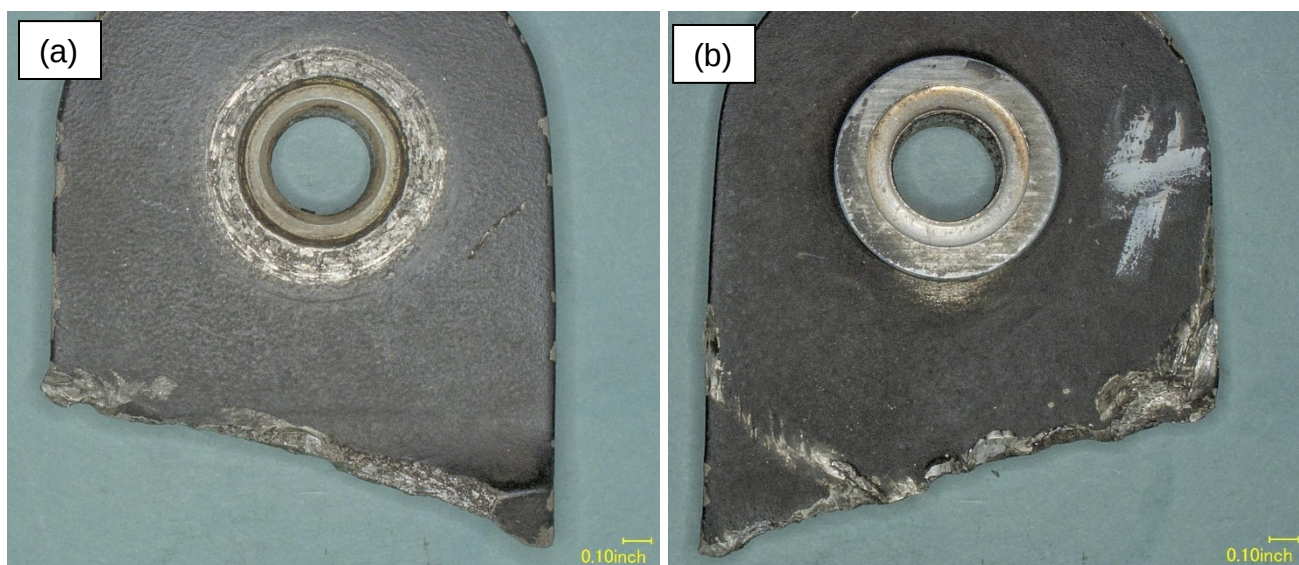


Figure 31 – The (a) inward and (b) outward-facing surfaces of the fractured support clevis 4.



Figure 32 – View of the fracture surface of the fractured support clevis 4.

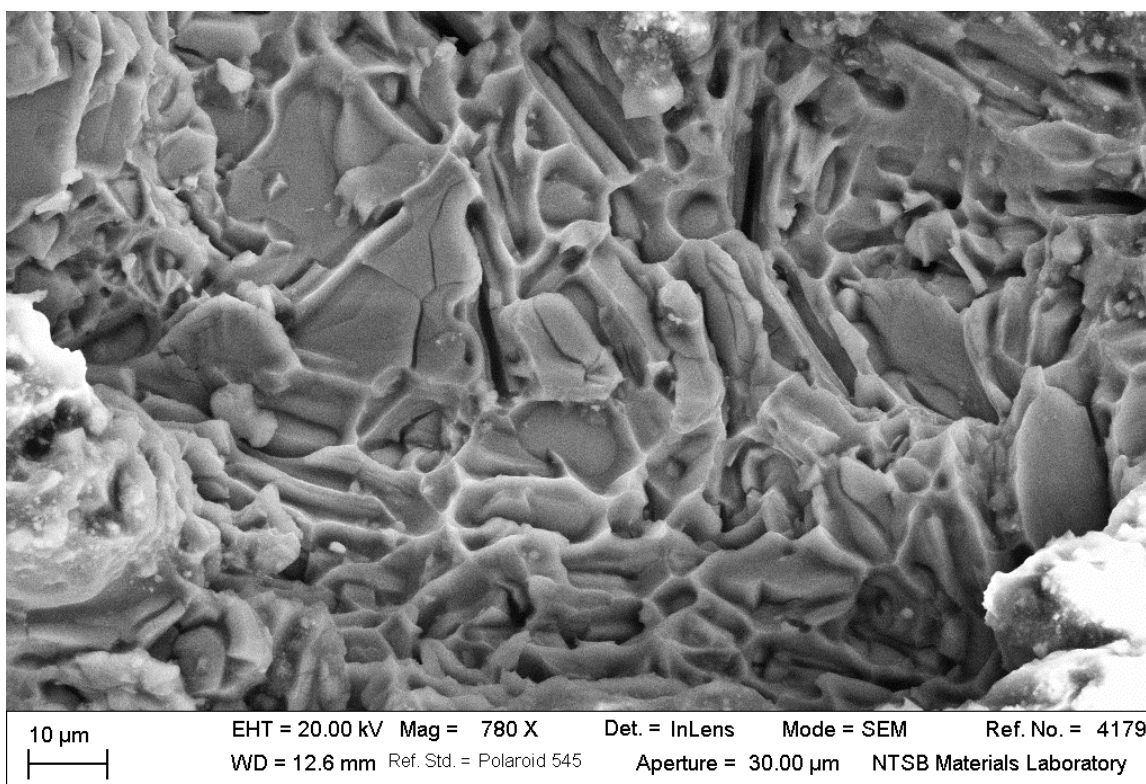


Figure 33 – SE micrograph of a typical area of the fracture surface of clevis 4, showing dimple rupture.

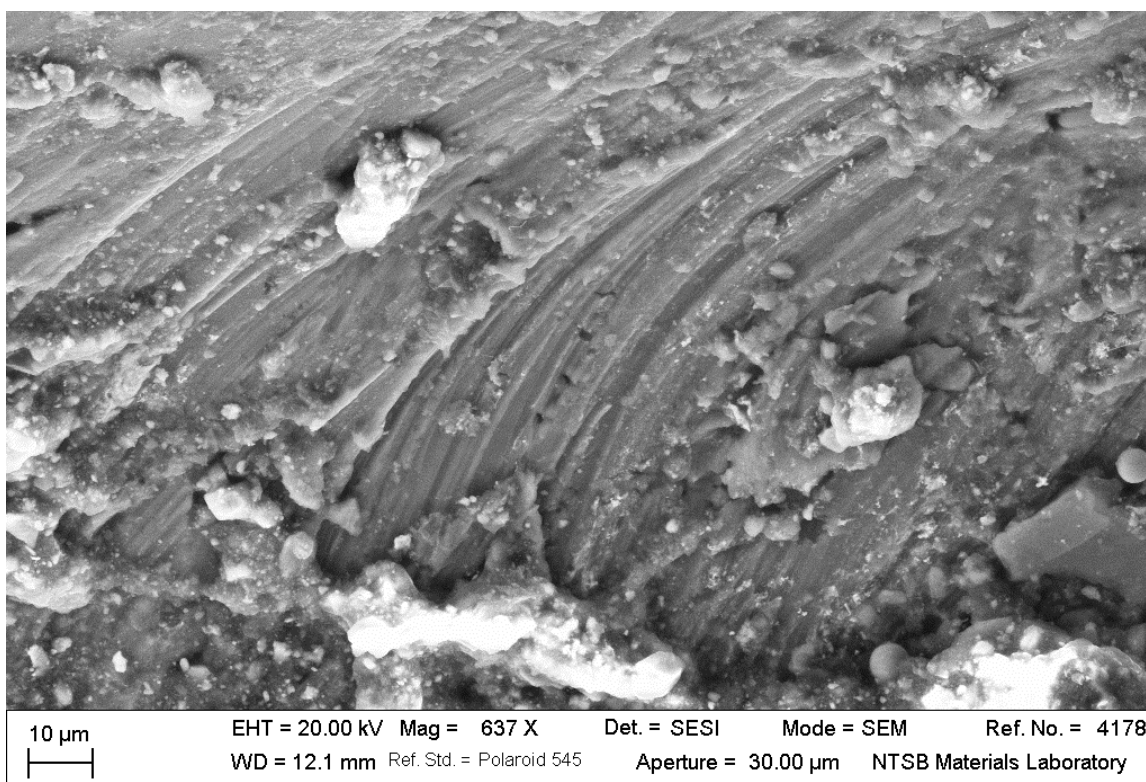


Figure 34 – SE micrograph of typical area of smearing on the clevis 1 fracture surface.

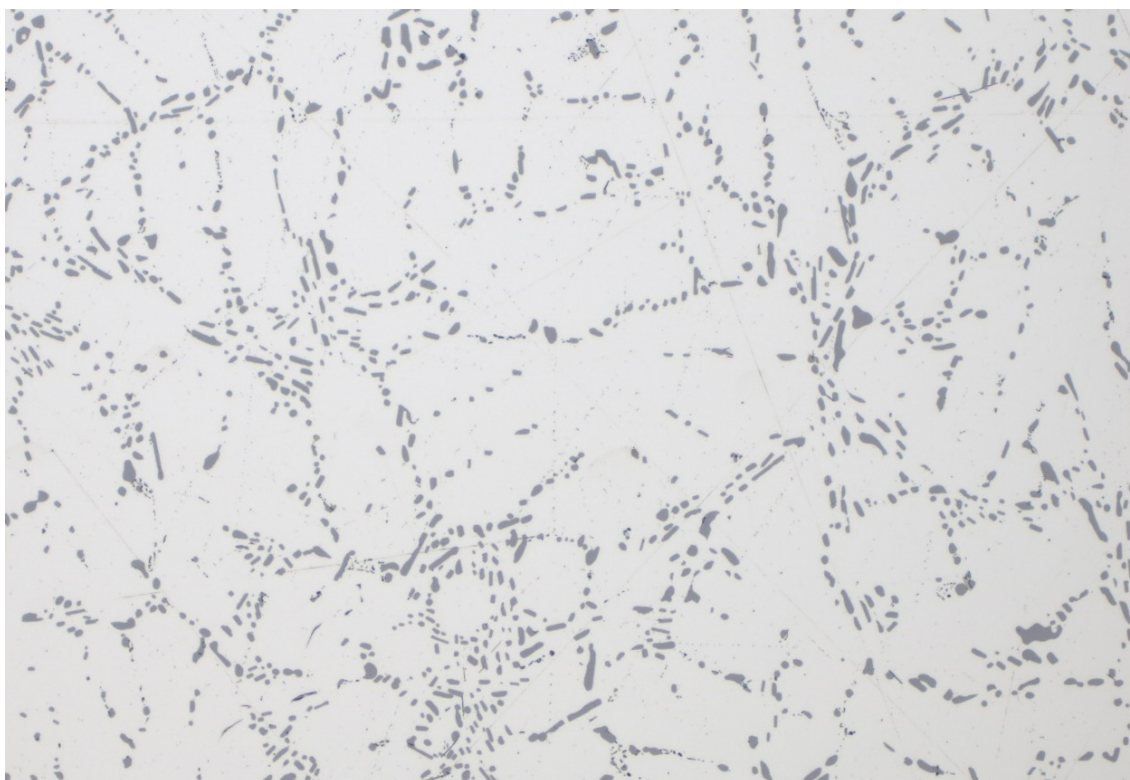


Figure 35 – Bright-field (BF) micrograph of a typical area of the clevis 3 microstructure, (~200X, etched Keller's Reagent).

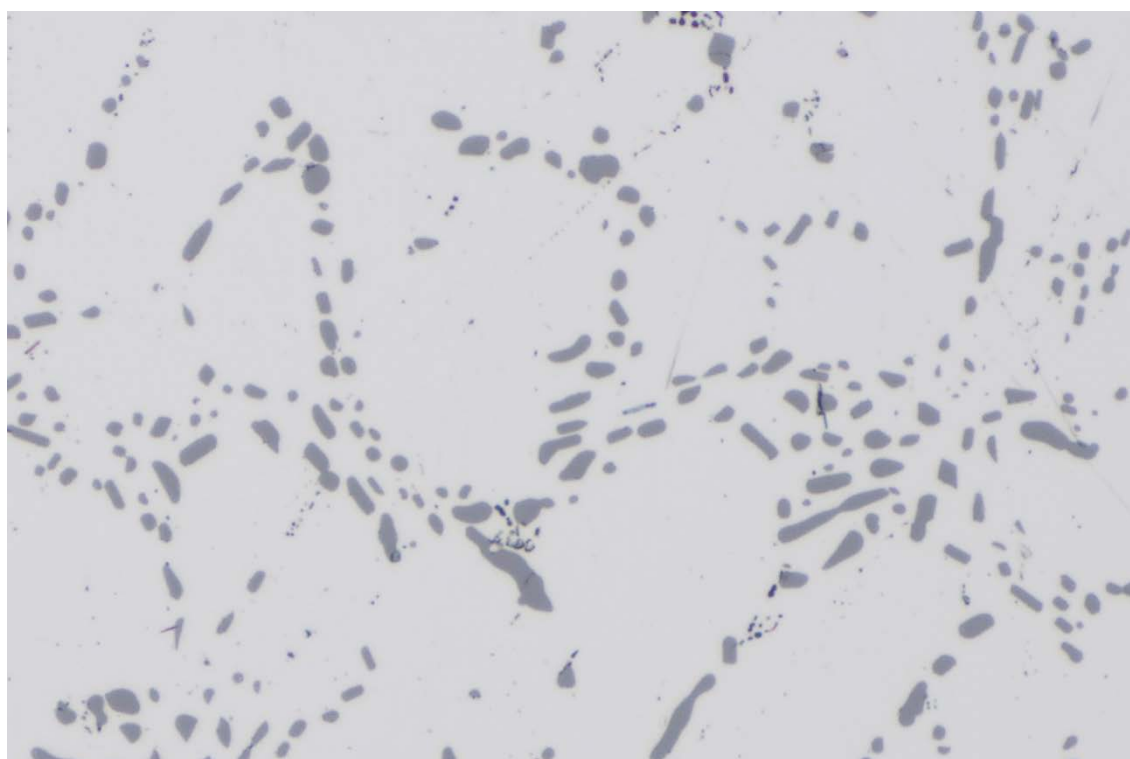


Figure 36 – BF micrograph highlighting the showing darker interdendritic high-Si phases in Figure 35 (~500X, etched Keller's Reagent) .



Figure 37 – The collective lever arms, as received.



Figure 38 – The faying surfaces of the collective lever arms, as received.

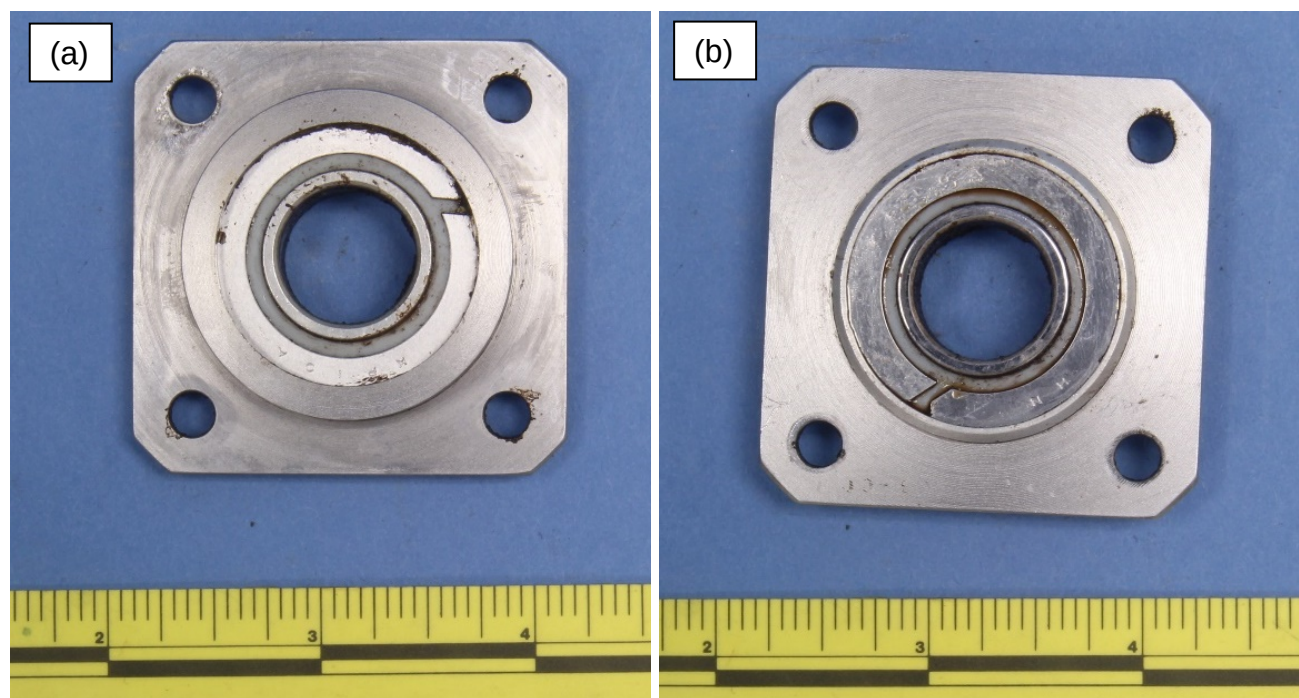


Figure 39 – The intact bearing and liner assembly, from the (a) outer and (b) inner surfaces.



Figure 40 – The fractured bearing liner and bearing race, after cleaning and grease removal.



Figure 41 – The bearing liner and race, viewed from the faces opposite those in Figure 40.



Figure 42 – The attachment bolt and spacer, as received.



Figure 43 – View of the spacer, after disassembly and cleaning, showing a dent on the side.



Figure 44 – View of the attachment bolt, after disassembly, showing the bend in the shaft.

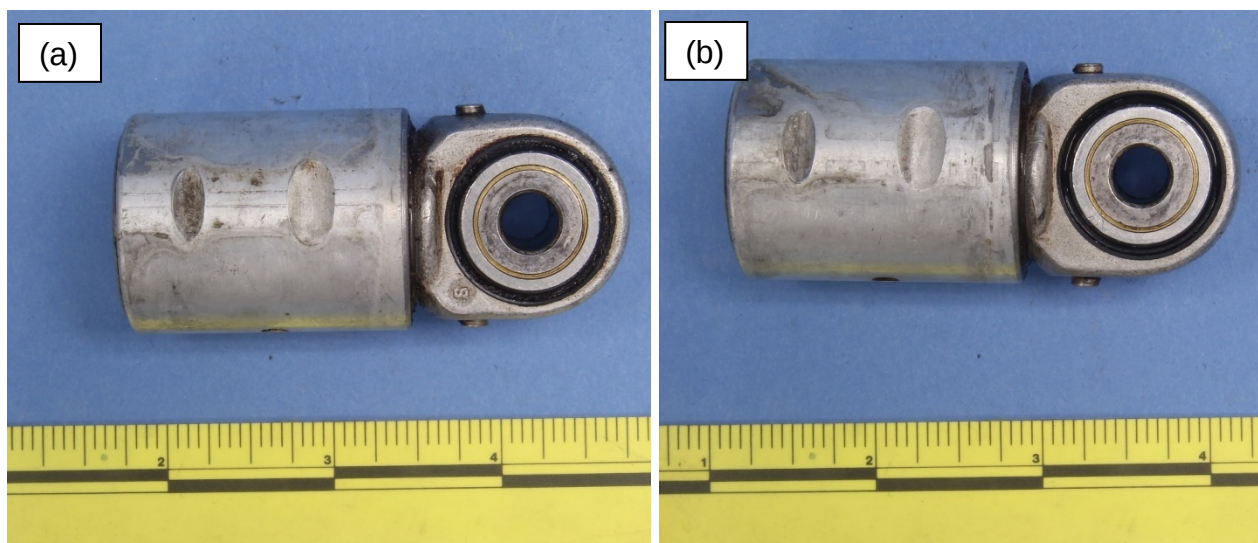


Figure 45 – View of the loose trunnion, shown after cleaning from opposite sides.