

NATIONAL TRANSPORTATION SAFETY BOARD

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



February 27, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 17-086

A. ACCIDENT INFORMATION

Place : Ronan, Montana
Date : July 7, 2017
Vehicle : Robinson R44 II
NTSB No. : WPR17LA143
Investigator : Stephen Stein, AS-WPR

B. COMPONENTS EXAMINED

Tail rotor drive shaft damper bearing assembly with support bracket pieces and piece of tail rotor drive shaft, Adel clamp with piece of insulated wire, and bulkhead pieces from bulkheads 6 and 7.

C. DETAILS OF THE EXAMINATION

Photographs of the tail end of the helicopter as it came to rest on scene are shown in figure 1. The tail boom was bent at the forward end just aft of the fuselage with the aft end shifted to the left relative to its original position. Both tail rotor blades were fractured at a similar location near the root end of each blade. Sliding contact marks and paint transfer corresponding to blade contact within the radius of blade rotation were present on the lower left side of the tail boom. As indicated in the upper left image in figure 1, vegetation adjacent to the engine exhaust was scorched consistent with continued engine operation after the helicopter came to rest.

The helicopter was moved to a hangar facility where it was examined by the NTSB investigator in charge with representatives from the Federal Aviation Administration (FAA) and Robinson Helicopter Company. A photograph of the tail rotor assembly before the teardown began is shown in figure 2. The pitch control tube was attached to the inboard end of the pitch control bellcrank, and the bellcrank position corresponded to a tail rotor blade pitch associated with thrust to the left (yaw to the right).

The cowling at the forward end of the tail boom was removed, and views of the interior of the tail boom are shown in figure 3. The damper bearing was attached to the drive shaft but was fractured from its support bracket assembly attached to the number 3 bulkhead. The drive shaft was intact but was bent, and insulated wires were wrapped around the shaft aft of the number 6 bulkhead. Although not visible in the pictures, the pitch control tube (located at the bottom of the tail boom) was fractured just aft of the

number 3 bulkhead. The control tube was also bent at locations aft of the number 5 bulkhead. The numbers 6 and 7 bulkheads were crushed and fractured.

During the teardown, the tail rotor blade pitch position was changed to the position corresponding to maximum thrust to the right, and a view of the pitch control bellcrank in the maximum right thrust position is shown in figure 4. In this position, the pitch control tube had translated approximately 5.5 inches aft of the position shown in figure 2.

An overall view of the tail rotor drive shaft and pitch control tube after disassembly from the helicopter is shown in figure 5. The pitch control tube is shown placed next to the drive shaft where the longitudinal relative positions corresponded approximately with the tail rotor blade pitch position as found at the start of the teardown (left thrust position). The drive shaft had an "S"-shaped bend mostly near the forward half of the shaft length, and the pitch control tube was bent in two places near the aft end. As shown in the lower image in figure 5, the pitch control tube was fractured at a location corresponding to the position of the damper bearing. The tube forward of the fracture was crushed and had transverse sliding contact marks within approximately 1 inch of the fracture.

Overall views of components submitted for examination are shown in figures 6 and 7. As assembled, the damper bearing is attached to a lower vertical support bracket that is in turn attached to an upper vertical support bracket. The upper end of the upper vertical support bracket is attached to the center of a transverse support bracket, and the ends of the transverse support bracket are attached to the aft side of the number 3 bulkhead. As shown in figure 6, the transverse support bracket was fractured in several locations, and the lower support bracket was fractured in two locations. A cut section of the tail rotor drive shaft was included as found in the damper bearing, and the drive shaft piece rotated freely within the damper bearing.

Pieces from the numbers 6 and 7 bulkheads shown in figure 7 had sliding contact damage consistent with contact with the drive shaft. A piece of the bulkhead remained attached to the Adel clamp, and the black bushing material within the clamp was displaced relative to its normal installed position. The insulated wire was fractured and damaged with exposed conductors. Pieces of wire of similar construction were photographed wrapped around the drive shaft during the teardown (see figure 3, lower image).

As installed, the tail rotor drive shaft is located directly below the upper vertical support bracket as shown in figure 6. However, the end pieces of the lower vertical support bracket that remained attached to the upper vertical support bracket and the damper bearing flange were rotated about each attachment bolt axis. Figure 8 shows relative positions of the components with mating fractures of the separated lower vertical support bracket piece aligned to mating fractures on the rotated end pieces. With mating fracture surfaces aligned in close proximity, the damper bearing and drive shaft were rotated counterclockwise (as viewed looking forward) relative to the lower end of the upper vertical support bracket.

The transverse support bracket was fractured at 5 locations; at the left and right sides of the upper vertical support bracket, in the flange corner above the vertical support attachments, and adjacent to the bulkhead attachments. Fracture features on all pieces of the transverse support bracket were examined using an optical stereomicroscope. On the fractures near the bulkheads and to the left of the vertical support bracket, the transverse support bracket was deformed adjacent to the fracture consistent with ductile overstress fracture from bending and/or compression loads. Many of the fracture features were obliterated by post-fracture contact damage, but fracture features were generally on slant planes consistent with ductile overstress fracture, and where fracture features were visible, rough matte gray fracture features were observed also consistent with ductile overstress fracture.

A closer view of the fractures adjacent to the upper end of the upper vertical support bracket are shown in figure 9. To the right of the vertical support bracket, the fracture through the transverse support bracket had little out-of-plane deformation consistent with a primary fracture under a primarily tension load. The fracture surface was partly damaged by post-fracture contact damage. However, observable fracture features were on slant planes with matte gray fracture features, features consistent with ductile overstress fracture. To the left of the vertical support bracket, the upper flange of the transverse bracket was bent with an "S" shape and the vertical flange was bent matching edges of the vertical bracket, consistent with a secondary fracture under a compression and bending load.

An optical examination of fracture surfaces associated with the lower vertical support bracket revealed out-of-plane deformation adjacent to the fractures consistent with bending and twisting loads associated with the fractures. The forward and aft surfaces adjacent to the fracture surfaces at each end had a more textured surface with secondary cracks and thinning deformation, features consistent with ductile overstress fracture. However, the fracture surfaces at each end had areas where fracture occurred in a plane perpendicular to the surface that appeared relatively flat and had curving boundaries.

The fracture surfaces on the separated piece of the lower vertical support bracket were further examined using a scanning electron microscope (SEM). An SEM image of one of the relatively flat areas on the fracture surface is shown in figure 10. At each end of the piece, fracture surfaces showed multiple areas with curving boundaries emanating from multiple origins at both the forward and aft sides of the bracket piece. Closer views of two of the flat regions at the forward and aft sides of the fracture at the lower end of the piece are shown in figure 11. Curving lines within the flat regions were consistent with progressive crack growth. However, the flat regions had relatively widely spaced crack propagation marks consistent with a relatively high stress concentration associated with fracture. Deformation was also observed adjacent to the flat regions, including secondary crack features such as those indicated in figures 10 and 12. The deformation

and crack progression marks were consistent with overstress fracture under cyclic load conditions. No evidence of fatigue crack growth was observed.¹

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Senior Materials Engineer

¹ Fatigue cracks initiate and grow at stress levels below the yield stress of the material. Although evidence of progressive crack growth under cyclic loading was observed on the fracture surface, evidence of plastic deformation on surfaces adjacent to the areas of progressive crack growth indicated the yield stress was exceeded, consistent with overstress loading of the part.



Figure 1. Views of the helicopter on scene showing the bent tail boom (upper left image), scorched vegetation near the exhaust (upper right image), and left side of the tail assembly (lower image). Images were provided courtesy of the FAA.

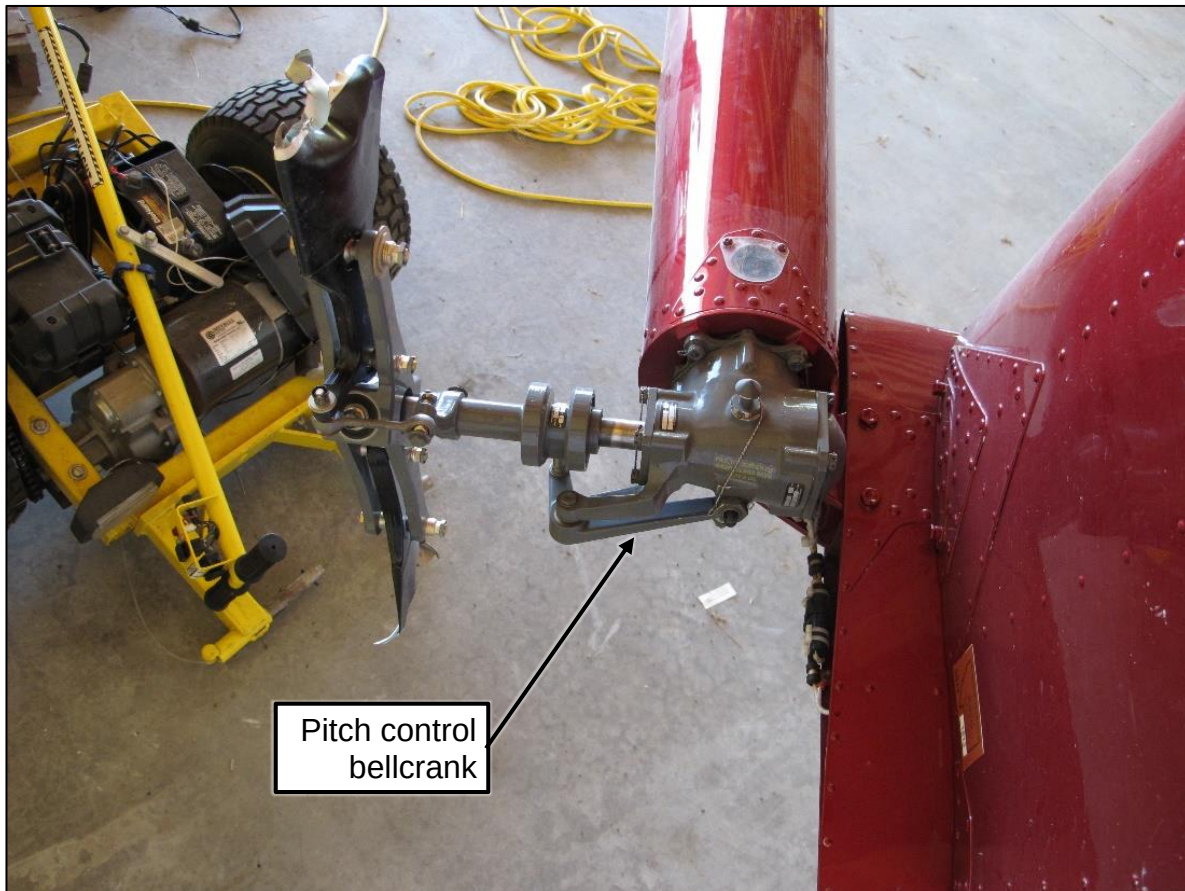


Figure 2. View of the tail rotor assembly looking forward and downward as photographed at the hangar before teardown. The pitch position of the blade is consistent with thrust to the left.

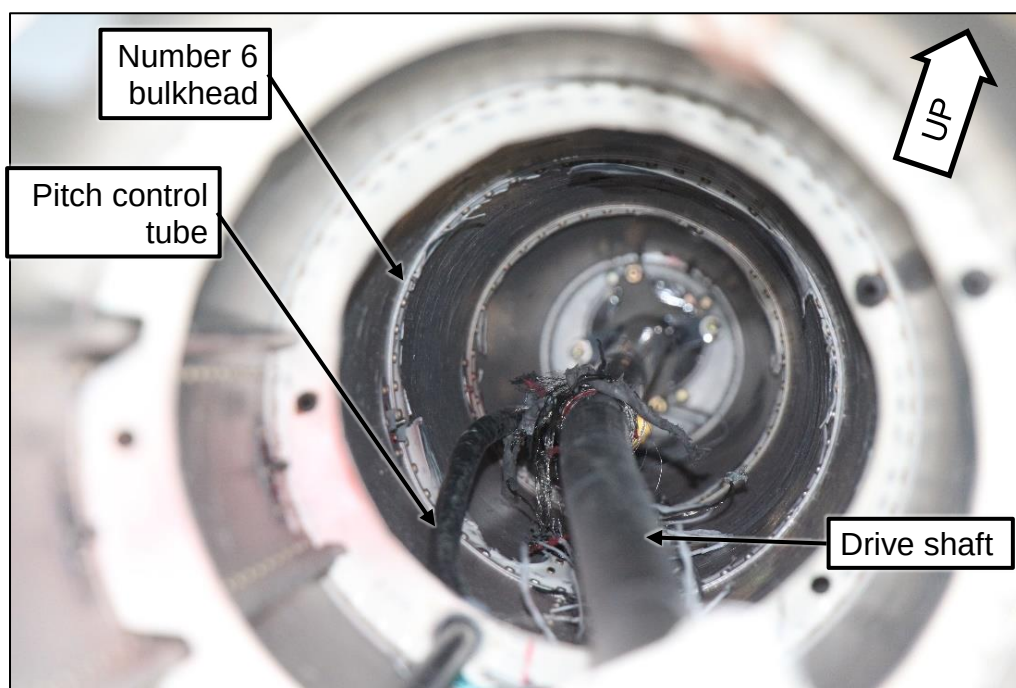
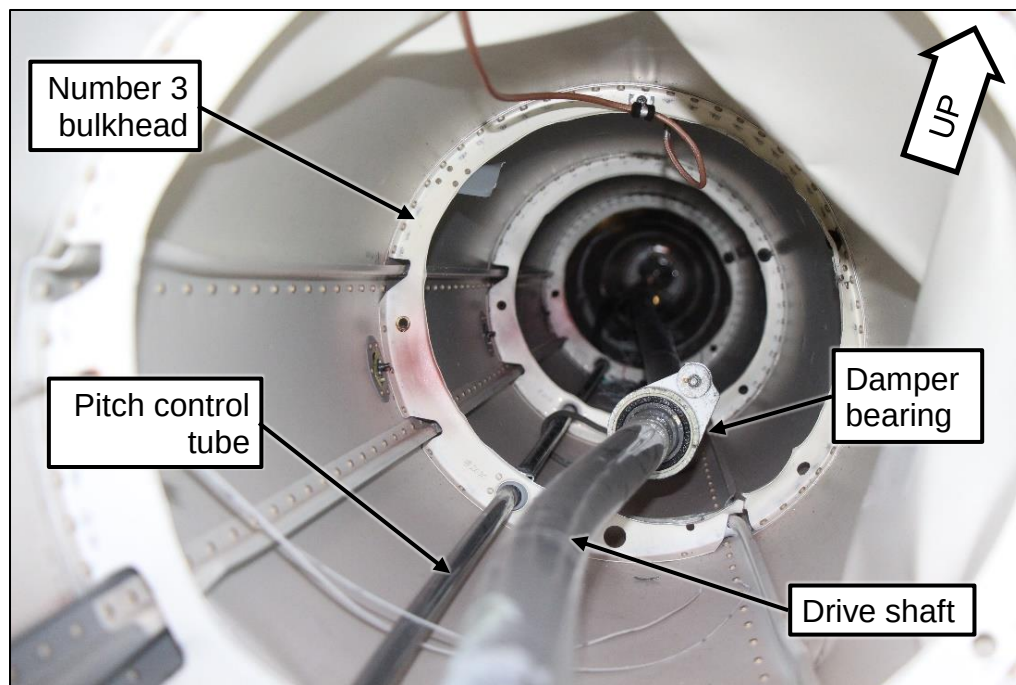


Figure 3. Views of the tail boom interior looking aft showing the damper bearing and number 3 bulkhead (upper image) and the damage further aft (lower image).

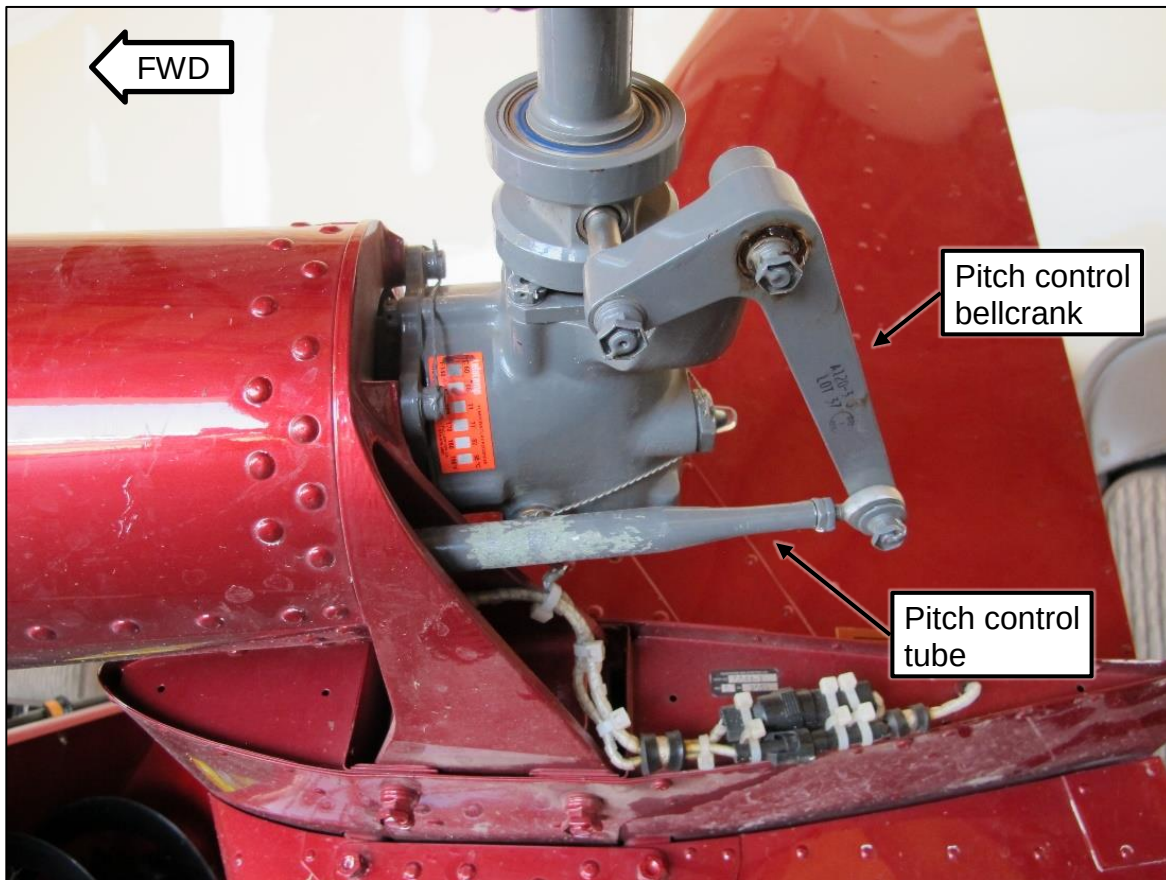


Figure 4. View of the lower side of the tail rotor assembly with the tail rotor blade pitch moved to the maximum right thrust position.

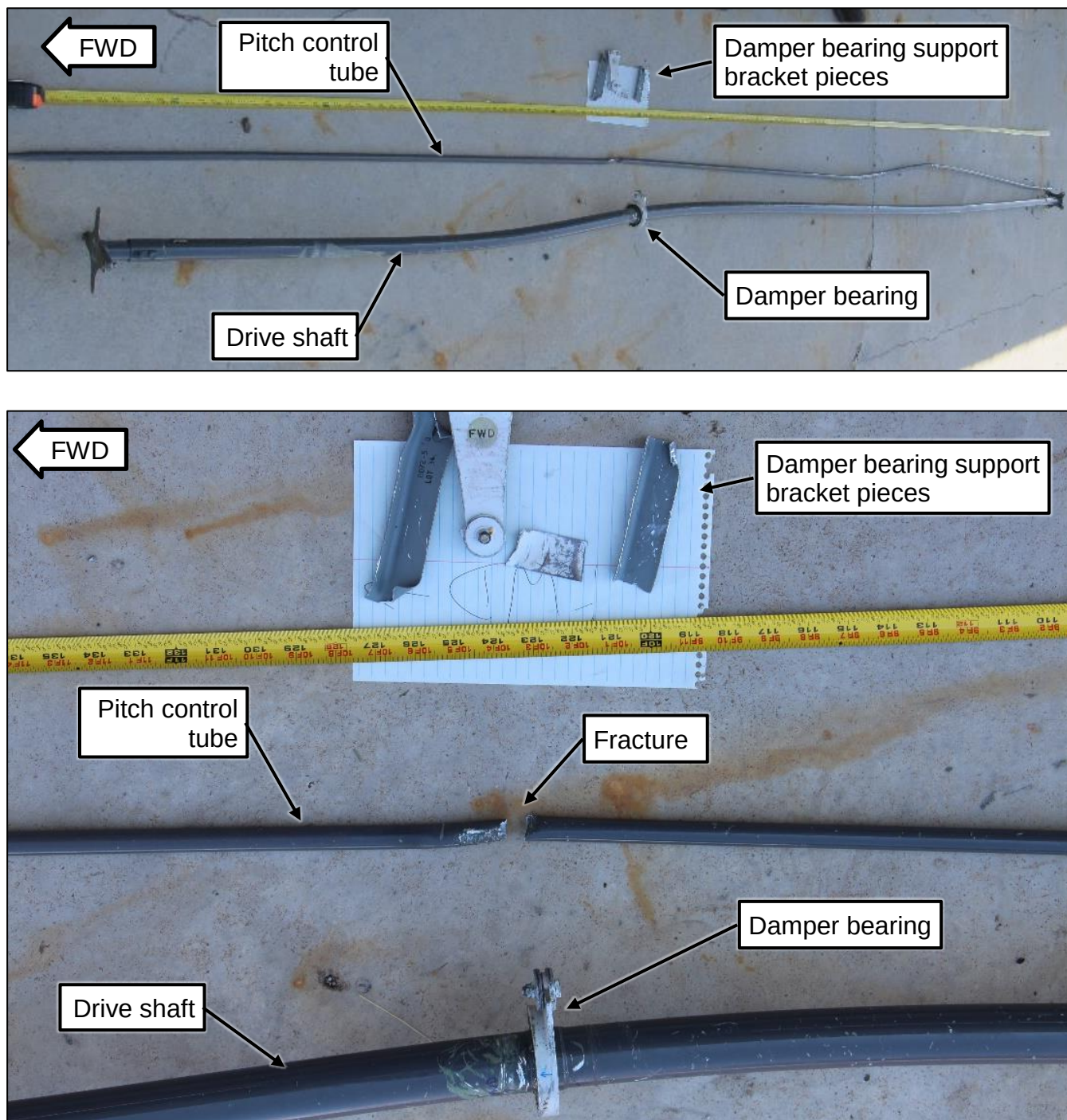


Figure 5. Photograph of the drive shaft, pitch change control tube, damper bearing, and damper bearing support bracket pieces after disassembly from the helicopter (upper image) with a closer view of the area associated with the damper bearing (lower image).

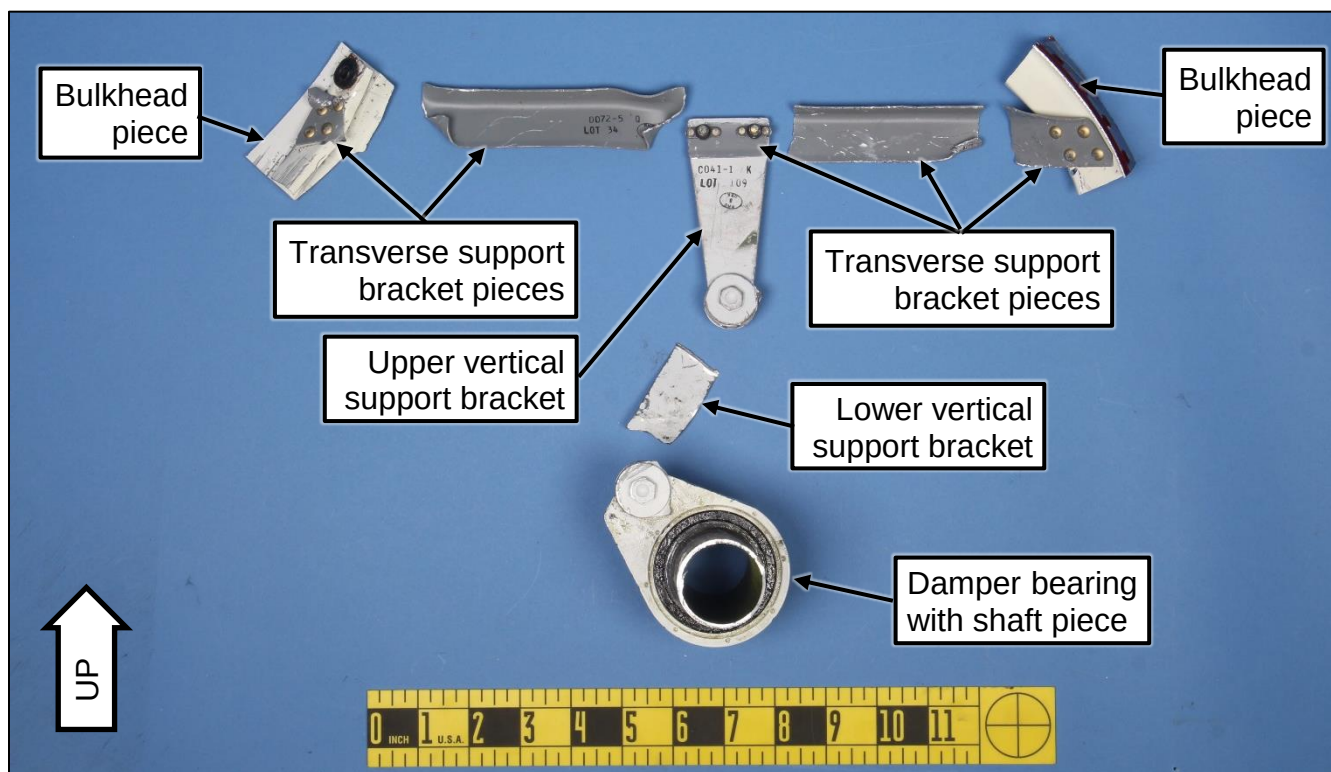


Figure 6. Overall view of the aft sides of the submitted pieces of the number 3 bulkhead, damper bearing support bracket, damper bearing, and drive shaft piece. The pieces are displayed in their approximate relative positions as installed on the helicopter, where the drive shaft is aligned directly below the upper vertical support bracket.



Figure 7. Submitted bulkhead pieces, Adel clamp, and insulated wire from the numbers 6 and 7 bulkhead area.

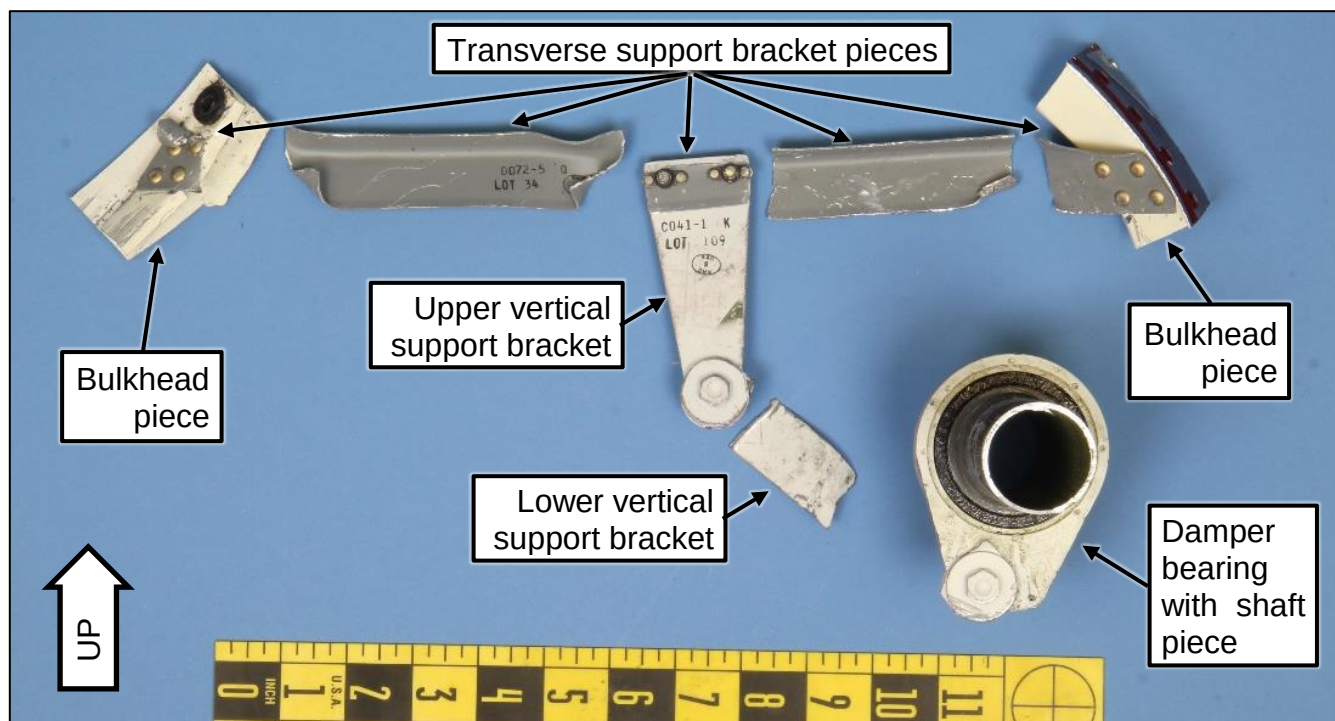


Figure 8. Submitted pieces shown in figure 6 displayed with mating fractures of the lower vertical support bracket pieces aligned in close proximity. As shown, the drive shaft and damper bearing were rotated counterclockwise relative to their normal installed position.

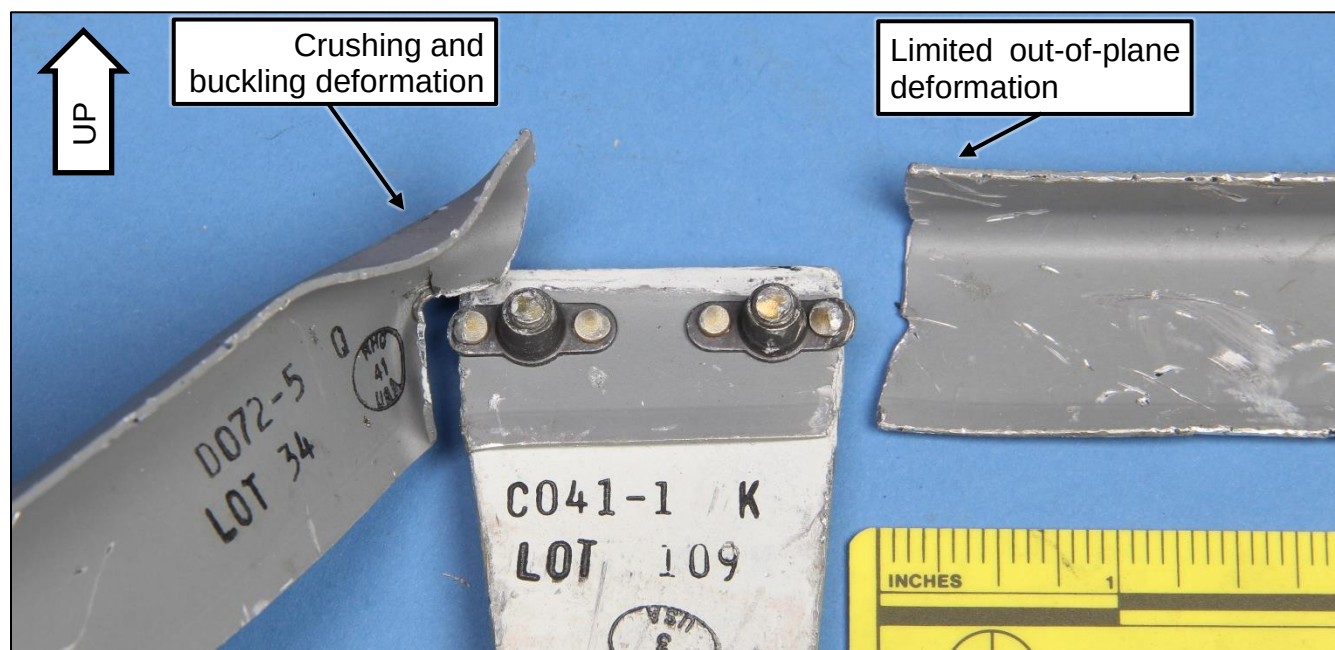


Figure 9. Closer view of mating fractures in the transverse support on either side of the upper vertical support bracket showing little out-of-plane deformation at the right side of the vertical support bracket consistent with a tension fracture and crushing and buckling deformation at the left side consistent with compression.

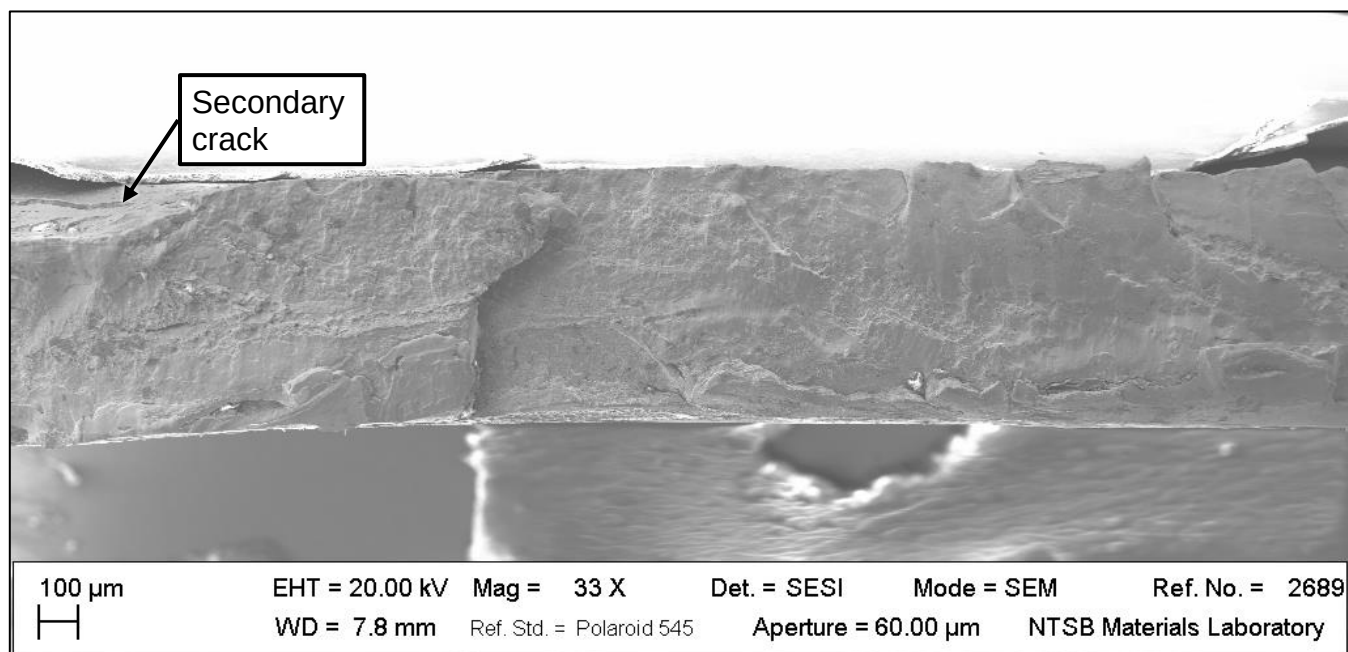


Figure 10. SEM image of fracture features at the lower end of the lower vertical support bracket.

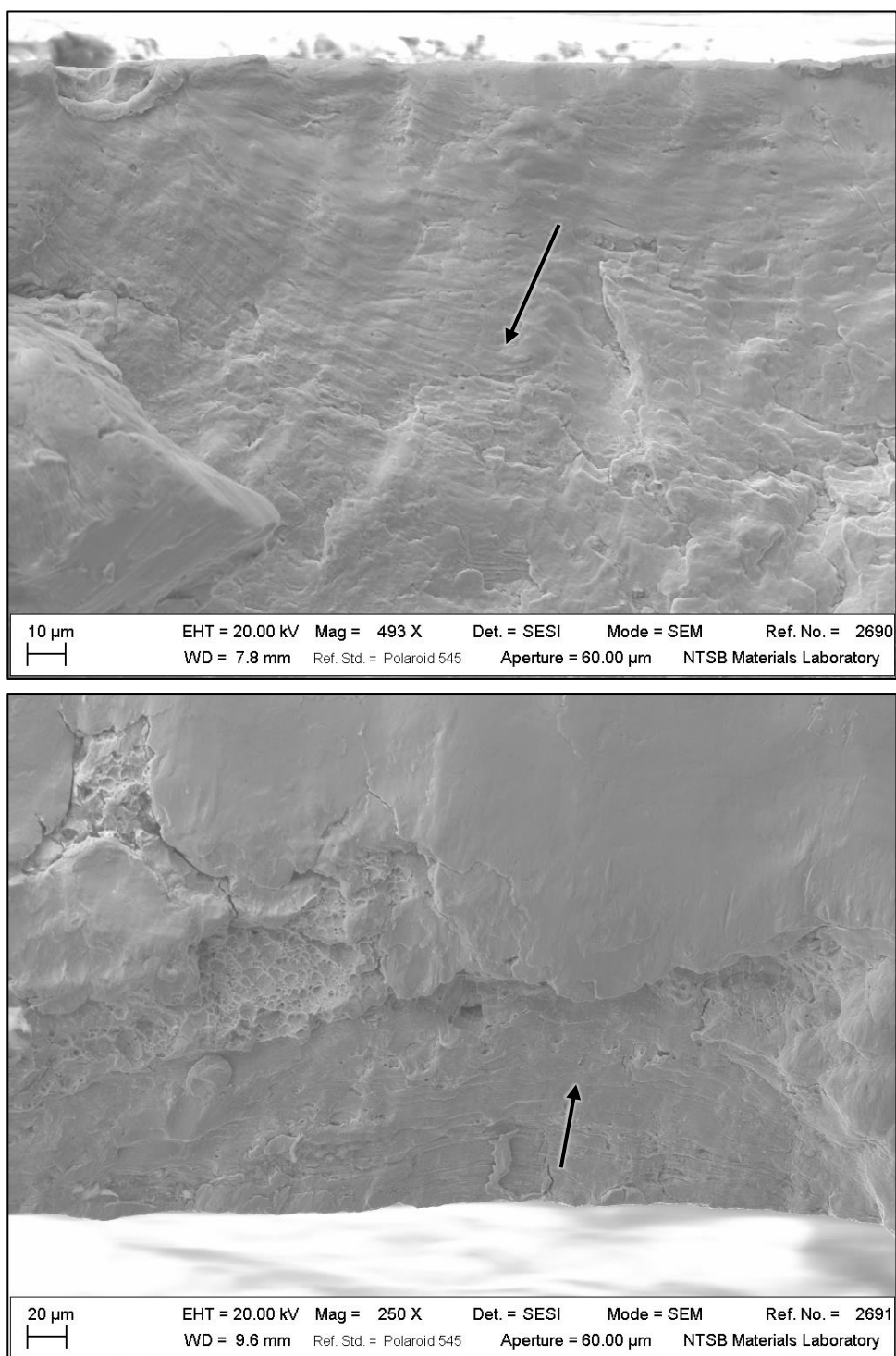


Figure 11. Closer SEM view of fracture features on the lower end of the lower vertical support bracket. Arrows indicate the propagation direction of cyclic overstress crack growth.

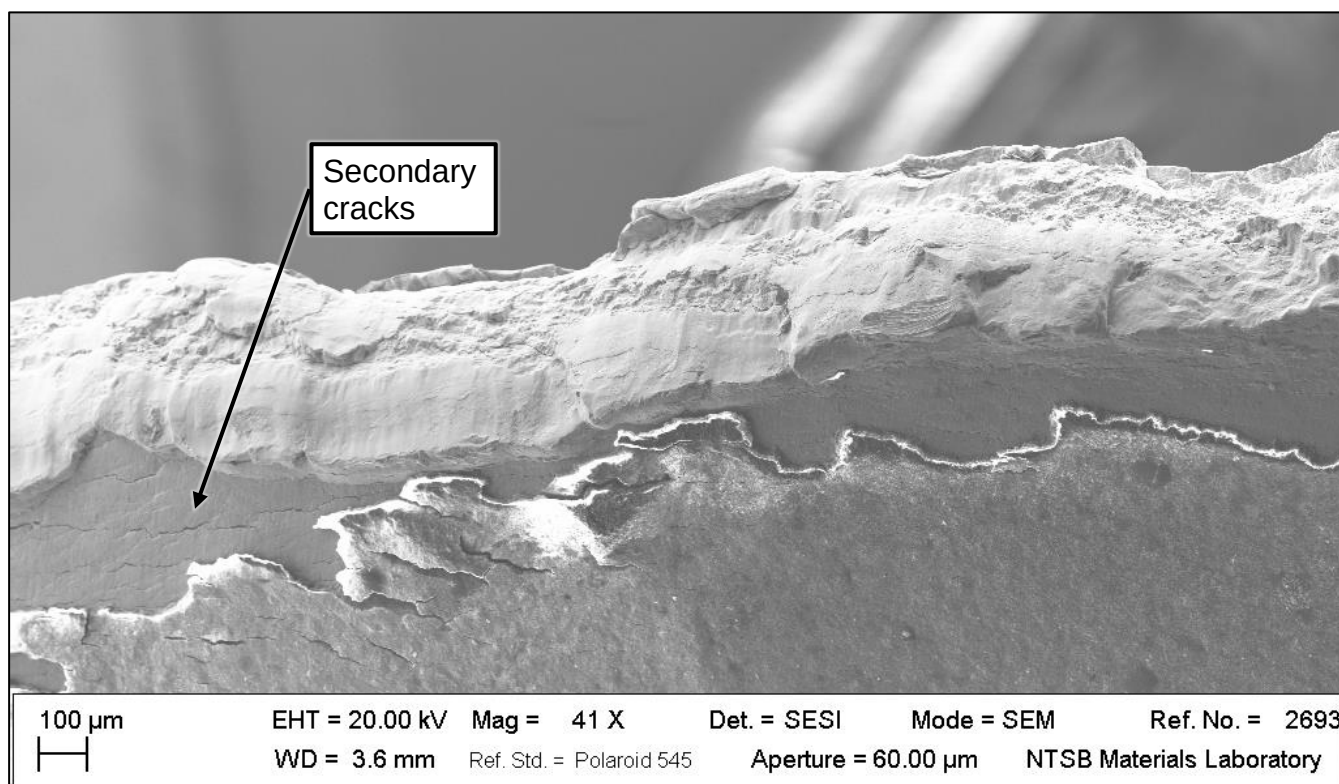


Figure 12. Secondary cracks adjacent to the fracture surface consistent with cyclic overstress fracture.