

NATIONAL TRANSPORTATION SAFETY BOARD

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



July 29, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-037

A. ACCIDENT INFORMATION

Place : Mokuleia, Hawaii
Date : February 22, 2020
Vehicle : Cessna Ector 305A, N65070
NTSB No. : ANC20FA024
Investigator : Noreen Price, AS-ANC

B. COMPONENTS EXAMINED

Fractured left rudder control cable pieces, left rudder cable pulley, left rudder cable pulley bracket, and sample of deposits from the area of the rudder pulley.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted components is shown in figure 1. The rudder control cable was fractured, and the cable had been cut forward and aft of the fracture to facilitate removal from the airplane for laboratory examination. The rudder pulley was received disassembled from its corresponding support bracket as shown in figure 1, and the pulley support bracket had been disassembled from the airplane structure. A plastic bag containing a sample of deposits collected from an area near the rudder pulley was also included with the submitted components.

The rudder control cable was composed of 7 strands (6 strands surrounding a core strand), and each strand consisted of 19 wires. The cable diameter and the diameter of an individual wire from one of the strands was measured using calipers near the cut end on the aft cable piece. The cable diameter measured 0.1320 inch, and an individual wire diameter measured 0.0080 inch.

A close view of the fractured ends of the rudder control cable is shown in figure 2, and closer views of each end of the fracture are shown in figure 3. On the forward piece, 17 wires from the core strand extended approximately $\frac{1}{2}$ to 1 inch beyond the rest of the wires, and on the aft piece, 16 wires from the core strand extended approximately $\frac{1}{2}$ to $\frac{3}{4}$ inch beyond the rest of the wires. Many wires associated with the outer strands surrounding the core strand were bent back. However, the lengths of almost all of the wires in the bent outer strands were shorter than the remaining core strand on each side of the fracture, indicating that segments were missing from most of the wires from the outer strands in the area of the fracture.

A closer view of the ends of several bent wires on the forward side of the fracture is shown in figure 4. Most of the wires were thinned to a chisel-like tip consistent with wear. Unlabeled arrows in figure 4 indicate wire ends showing a chisel-like wear pattern. Among the wires from the core strand that extended past the surrounding strands, 9 of the 17 wires on the aft side were thinned through at least half the wire diameter, and 7 of 16 wires on the forward side were thinned through at least half the wire diameter.

Black deposits covered the surface of the cable in the area of the fractured and bent wires within 2.5 inches both forward and aft of the core strand fracture. The fractured end on the aft cable piece was submerged in a beaker of acetone while cleaned for 5 minutes using an ultrasonic cleaner. A view of the resulting cleaned fracture is shown in figure 5. The cleaned fracture was further examined using a scanning electron microscope (SEM), and an SEM image of fractured core strand wires at the forward end of the cleaned cable piece is shown in figure 6. Nine of the wires from the core strand showed necking deformation¹ consistent with ductile overstress fracture.

A view of wire ends on outer strands are shown in figure 7. Most of the wires on the indicated outer strand were worn to a chisel-like tip as were many of the other wire ends visible in figure 7. Some of the chisel-like ends were also bent back and deformed into a curled shape.

Close views of the rudder pulley bracket are shown in figure 8. The bracket was partly covered with black deposits. Areas around the through-hole at the forward side of the bracket and near the cotter pin at the lower aft side of the bracket had missing paint and had a relatively reflective textured appearance consistent with abrasion from contact with cable wires as indicated in the upper right and lower left images in figure 8. A cable wire was observed lodged in the hole for the cotter pin in the lower aft side of the bracket as indicated in the lower left image in figure 8.

A close view of a sample of the deposits collected from the area near the rudder pulley is shown in figure 9. Silvery flecks consistent with chips of aluminum were observed scattered throughout the sample. However, it was noted that the sample was collected after cutting and drilling operations were completed to remove the cockpit floor to gain access to the rudder control cable and pulley components. The sample also contained flakes of green material appearing consistent with green primer. Finally, the sample contained many wire pieces consistent with worn control cable wire segments.

Samples of black deposits were taken from surfaces of the control cable near the fracture and from the deposits collected from the area near the rudder pulley. The samples were analyzed using a Varian IR600 Fourier-transform infrared (FTIR) spectrometer with a diamond attenuated total reflectance (ATR) accessory in accordance with ASTM E1252-98 (American Society for Testing Materials E1252-98: Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis. Results showed spectra consistent with grease.

¹ Necking is permanent deformation of a ductile material that results in a reduced cross-section at the location of fracture.

A close view of the pulley is shown in figure 10. The pulley overall had an appearance consistent with a fiber-reinforced polymer construction around a central bearing. In examining the cable guide groove in the pulley, the groove appeared deeper with a smaller root radius around approximately one quarter of the circumference, features consistent with cable contact wear as indicated in figure 10. Views of the groove profile in the worn quadrant and in another area of the pulley are shown in figure 11. The dashed line in the upper image in figure 11 is a trace of the profile in the lower image, which shows the difference in wear in the worn quadrant. The pattern of wear in the one quadrant of the pulley relative to the other quadrants was consistent with the pulley not rotating while in contact with the moving control cable.

The bearing for the pulley was held by hand, and the pulley rotated smoothly without binding. The coating on the interior faces of the pulley support bracket where it mated to the bearing inner race was intact and showed no evidence of relative sliding between the bearing and the bracket. The pulley was then reassembled into the bracket and was rotated. The pulley rotated by hand 360 degrees in both directions without binding or contacting the cotter pin.

Matthew R. Fox, Ph.D.
Senior Materials Engineer

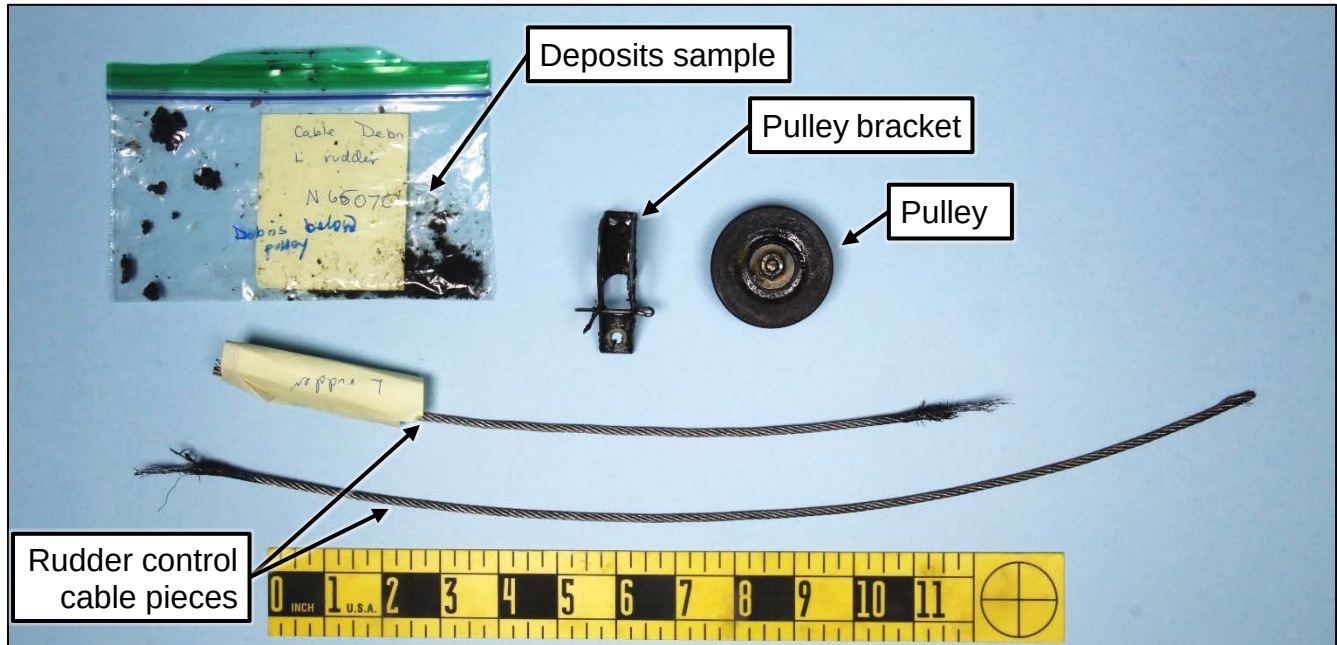


Figure 1. Overall view of the submitted components.

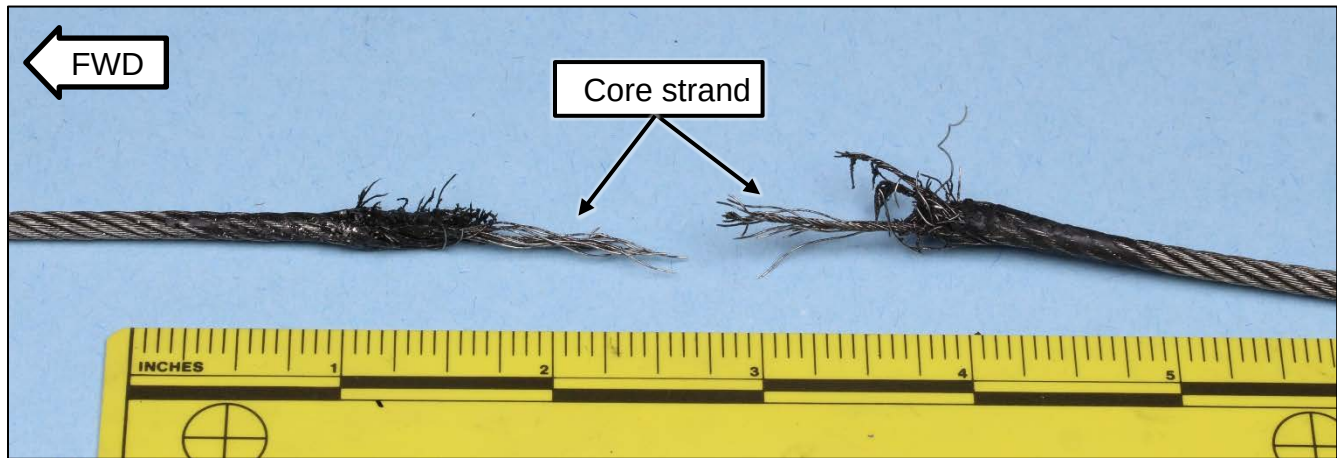


Figure 2. Fractured ends of the submitted rudder cable pieces. The core strand extended approximately an inch beyond other strands on each side of the fracture, and most of the surrounding strand wires were bent back and covered in black deposits.

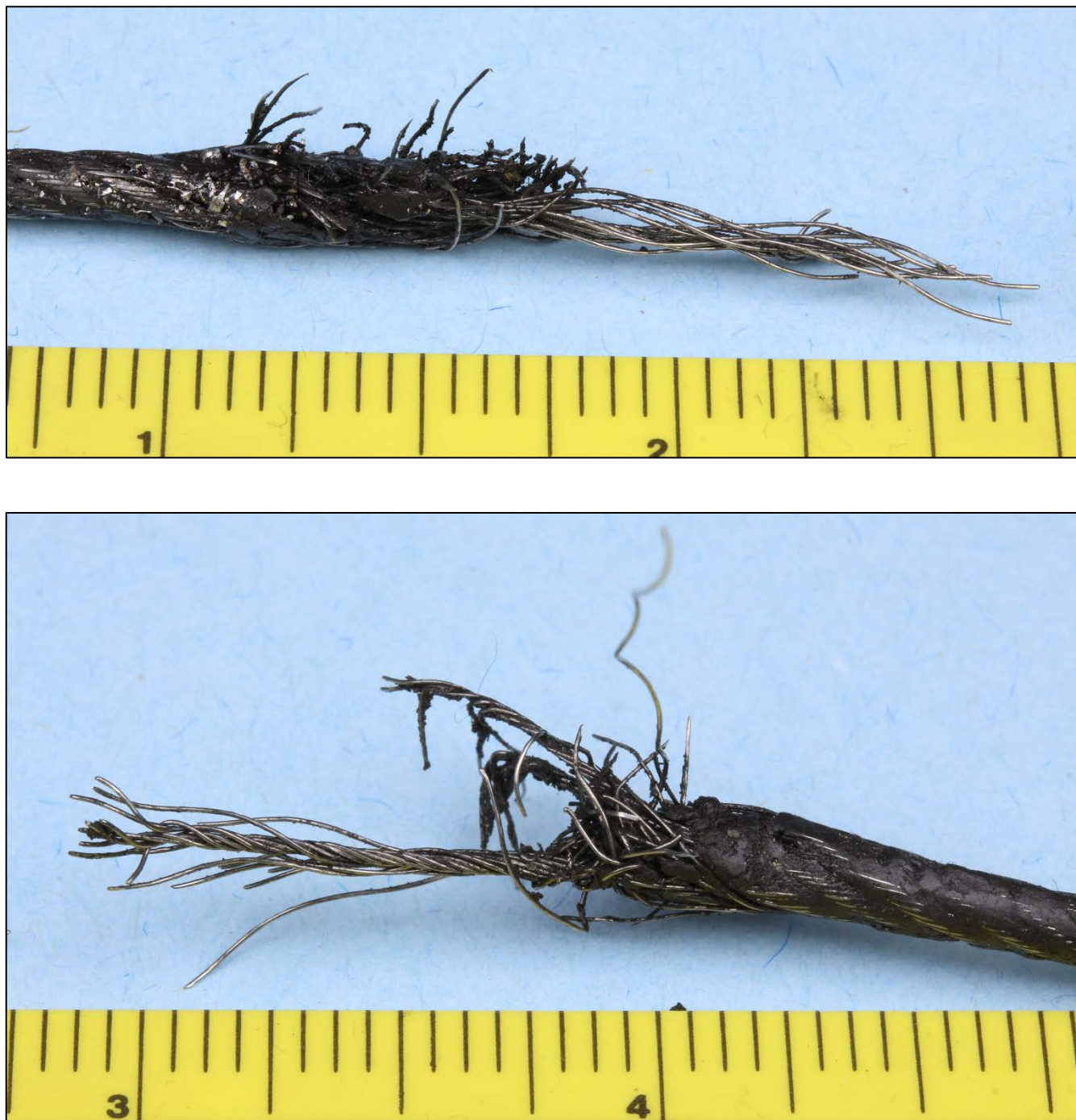


Figure 3. Closer views of the fracture surfaces on the forward (upper image) and aft (lower image) cable pieces showing bent strands and black deposits on the cable near the fracture.



Figure 4. Closer view of individual wires from strands that were bent back. The ends of many wires from the outer strands were worn to a chisel-like end such as the wires indicated with unlabeled arrows.

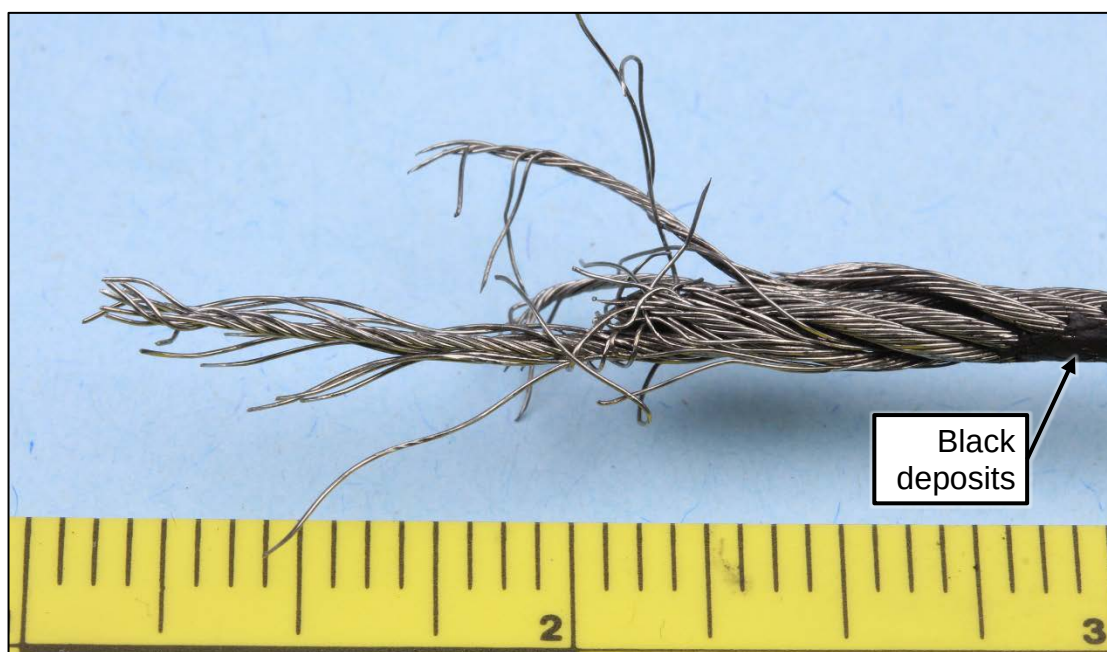


Figure 5. Overall view of the fracture on the aft cable piece after cleaning for 5 minutes in an ultrasonic cleaner while submerged in acetone. Some black deposits remained on the cable after cleaning as indicated.

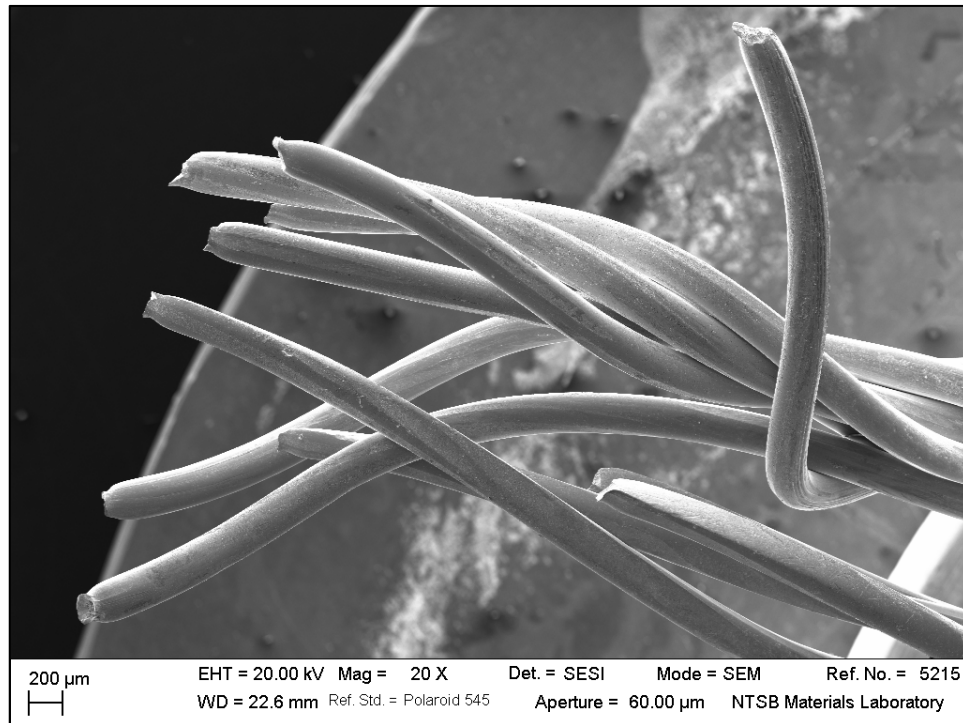


Figure 6. SEM image of individual wires from the core strand on the aft cable piece showing necking deformation associated with fractures on several wires.

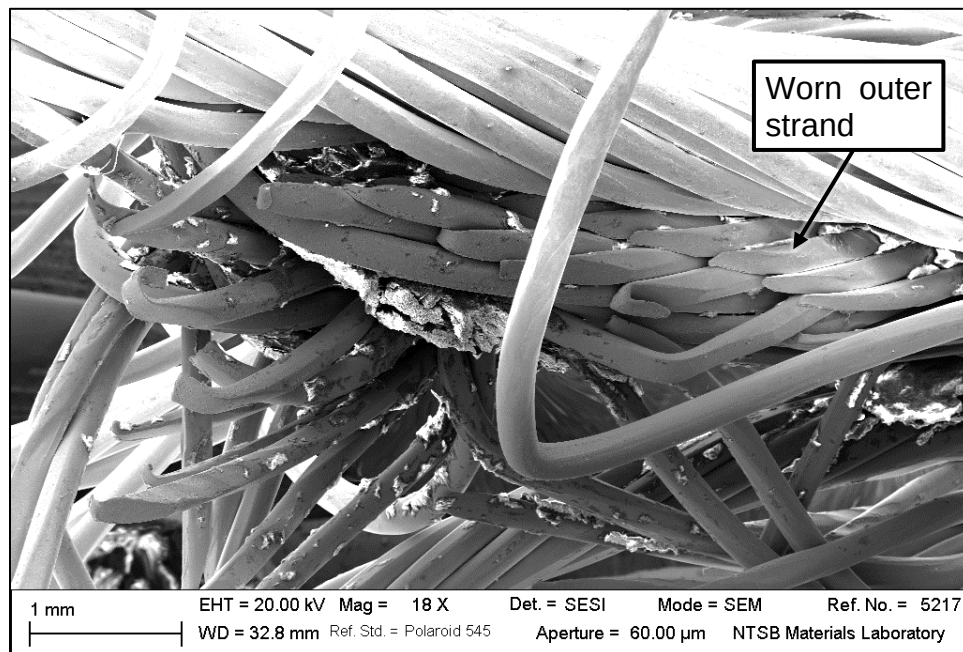


Figure 7. SEM image of wire ends on an outer strand on the aft cable piece showing wear through the thickness of wires in the strand, leaving chisel-shaped wire ends.

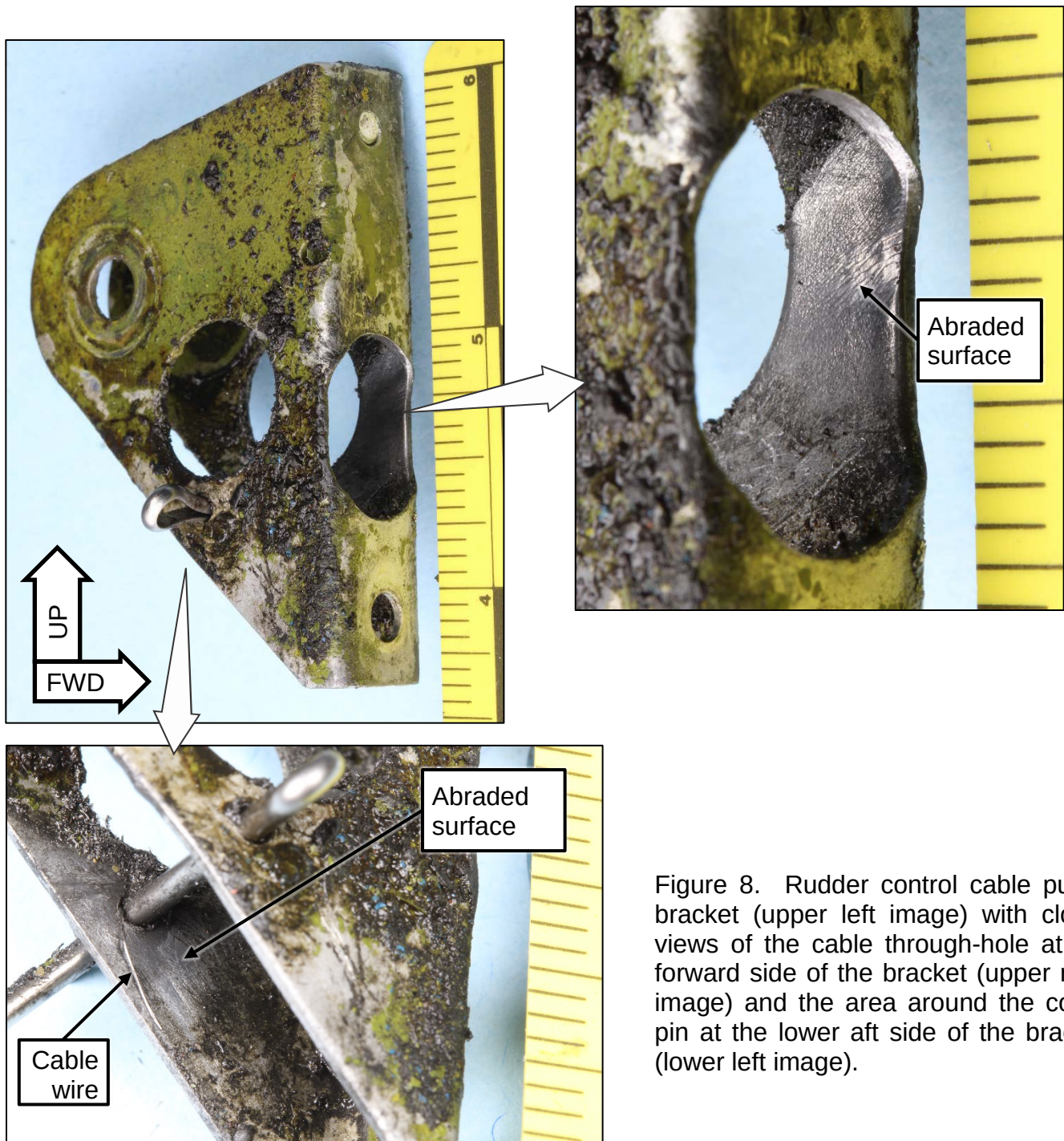


Figure 8. Rudder control cable pulley bracket (upper left image) with closer views of the cable through-hole at the forward side of the bracket (upper right image) and the area around the cotter pin at the lower aft side of the bracket (lower left image).



Figure 9. Sample of deposits collected from the rudder pulley area. Black deposits were mixed with chips of green primer, metal shavings, and wire fragments.

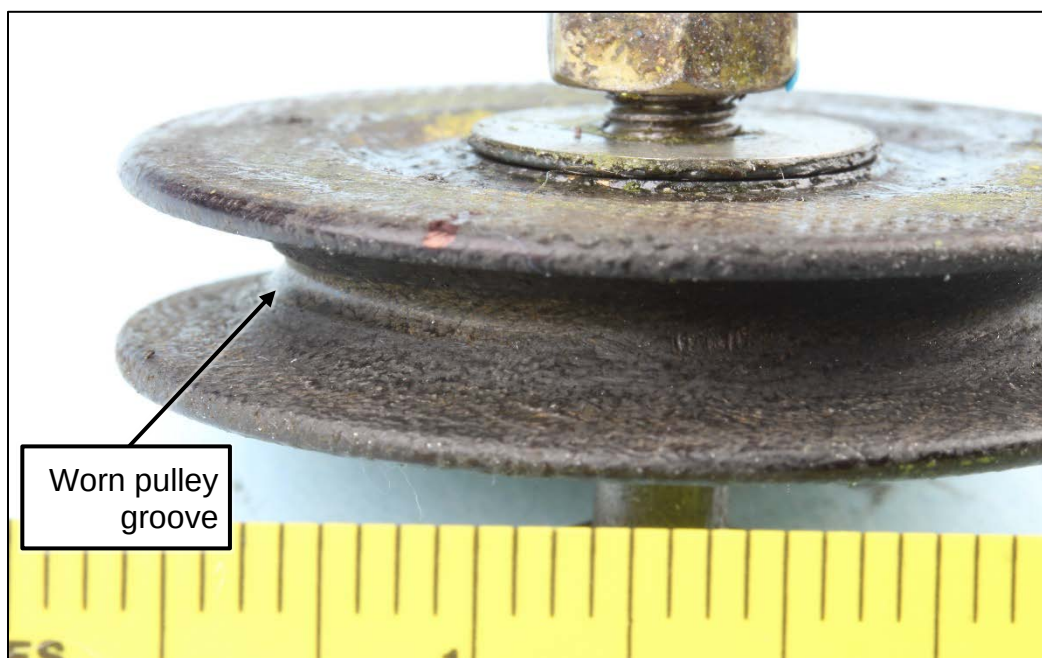


Figure 10. Close view of the pulley showing wear at the root of the pulley groove.

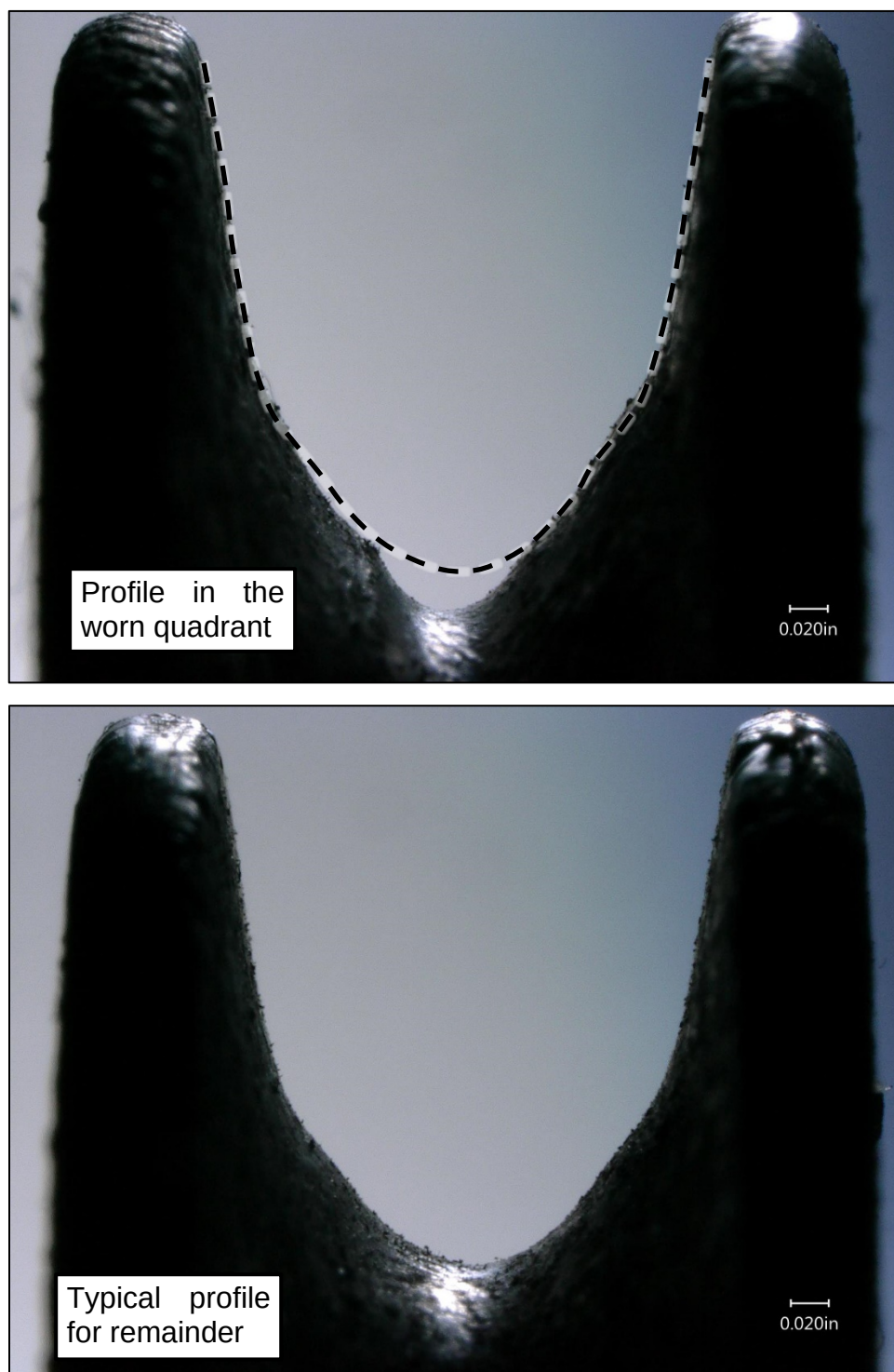


Figure 11. Profile view of the rudder pulley groove in the worn quadrant (upper image) and a typical groove profile for the remainder of the pulley circumference (lower image). A dashed line in the upper image represents a trace of the groove profile shown in the lower image.