NATIONAL TRANSPORTATION SAFETY BOARD

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

June 6, 2006

MATERIALS LABORATORY FACTUAL ADDENDUM — Report No. 06-010B

A. ACCIDENT

Place	:	Miami, Florida
Date	:	December 19, 2005
Vehicle	:	Grumman G-73T Mallard, N2969
NTSB No.	:	DCA06MA010
Investigator	:	Brian Murphy, AS-40

B. COMPONENTS EXAMINED

Pieces of the wing box beam.

C. DETAILS OF THE EXAMINATION

This report is an addendum to *Materials Laboratory Factual Report 06-010 and* documents the examination of a repaired area of the rear Z-stringer for the wing box beam lower skin panel at right wing station (WS) 48. Also, the condition of each of the twelve slosh holes in the webs of the Z-stringers is summarized. More details of the wing construction for the Grumman model G-73 Mallard airplane are provided in *Materials Laboratory Factual Report 06-010*.

Overall views of the piece containing the rear Z-stringer repair at right WS 48 are shown in figures 1 and 2, which display the interior and exterior surfaces, respectively. The piece shown in figures 1 and 2 had been cut both in the field before being sent to the Safety Board's Materials Laboratory and during the Safety Board's Materials Laboratory examination as described in *Materials Laboratory Factual Report 06-010*.

The repair for the rear Z-stringer consisted of two nested "L"-shaped angle pieces attached to the lower flange and aft side of the web and two nested "L"-shaped angle pieces attached to the upper flange and forward side of the web. Each repair angle was nominally 0.040 inch thick. The repair angles that had a faying surface with the Z-stringer were approximately 9.25 inches long, and the other two repair angles were approximately 5.67 inches long. The repair angles were centered lengthwise approximately at the slosh hole in the rear Z-stringer web just outboard of right WS 48. The vertical legs of the repair angles had holes approximately 0.43 inch in diameter at a location coinciding with the slosh hole in the web of the rear Z-stringer.

As shown in figure 1, most of the interior of the piece was covered with a reddish-brown sealant consistent with the fuel tank sealant observed throughout interior surfaces of the accident airplane wing fuel tanks. One area outboard of right WS 48 and at the aft side of the rear Z-stringer had a gray colored sealant. A closer view of the area of gray sealant is shown in figure 3.

Most of the Z-stringer repair fasteners through the lower skin had heads that were flush to the skin surface. However, one rivet at the center of the repair area had a protruding head as indicated in figure 2. A closer view of the protruding-head rivet is shown in figure 4.

A section of the rear Z-stringer containing the repair and adjacent skin was cut from the remainder of the piece shown in figures 1 and 2 to facilitate the removal of the sealant and subsequent removal of repair fasteners. Sealant was removed by soaking the piece in acetone and scraping and pealing the sealant away using wooden tongue depressors.

A view of the repair in the area of the slosh hole at the aft side of the rear Z-stringer after sealant removal is shown in figure 5. As indicated in figures 5, the rear Z-stringer was fractured, and the mating sides of the fracture were gaped open slightly at the visible upper flange. The repair angle brackets on the aft side of the Z-stringer were cracked at the slosh hole location from the forward side of the protruding head fastener through the slosh hole and up to the top of the vertical legs. In the most aft repair angle, sanding or grinding marks with missing paint were observed around the slosh hole in the vertical leg and on portions of the horizontal leg. During sealant removal, it was noted that reddish-brown sealant was not present in the local area in and around the sanding or grinding marks, and gray sealant was adhered directly to the repair angle surface.

A close view of the repair in the area of the slosh hole at the forward side of the rear Z-stringer after sealant removal is shown in figure 6. Both repair angles at the forward side of the Z-stringer were fractured at the locations shown in figure 6.

The area around the protruding-head rivet on the lower surface of the skin was covered with a sealant. The sealant was removed and the area was cleaned using acetone and a brush. The area is shown in figure 7 after sealant removal and cleaning. Cracks were observed emanating forward and aft of the rivet head. The area around the rivet head had missing paint with sanding or grinding marks in the skin.

Repair fasteners, Z-stringer fasteners, and rib attach angle fasteners in the area were removed mostly by drilling out the head of the fasteners with a countersink drill bit followed by pushing the shank out with a hammer and punch. Some heads were also removed using a chisel and hammer.

The protruding-head fastener shown in figure 7 was drilled part way with a countersink drill bit followed by drilling with a 5/16 inch diameter drill bit, all the while attempting to drill only the head and shank of the fastener without contacting the underlying skin. Once the head was mostly drilled out, a small chisel was applied from the inboard and outboard sides to remove the remaining portion of the head, and a small punch was used to push the shank out of the hole. The lower surface of the skin in this area is shown in figure 8 after fasteners were removed.

The repair angles were bonded to each other and to the rear Z-stringer. To facilitate the examination of the fractures and cracks in the rear Z-stringer and the repair angles, the repair angles were separated from the rear Z-stringer by prying the angles from the Z-stringer with acetone and a wooden tongue depressor. To separate the crack surfaces in the repair angles at the aft side of the Z-stringer, a cut was made nearly to the hole for the protruding head rivet, and then the remaining ligament between the cut and the fastener hole was fractured in the lab.

All crack and fracture surfaces on the repair angles were on slant planes consistent with overstress fracture. No evidence of preexisting damage such as fatigue cracking was observed on the repair angle surfaces.

Portions of the rear Z-stringer fracture surfaces were relatively flat and perpendicular to the longitudinal axis, features consistent with fatigue. The fracture surface at the inboard side of the fracture was cleaned using acetone, soapy water, and a brush followed by ultrasonic cleaning in soapy water, and the resulting fracture surface is shown in figure 9. Flat fracture features with curving crack arrest lines consistent with fatigue were visible above the slosh hole up to the dashed line position in figure 9. The remainder of the upper flange beyond the dashed line position was fractured on a slant plane consistent with overstress fracture. Below the slosh hole, fracture features were mostly obliterated by post-fracture corrosion and contact damage. The fracture plane nearest the slosh hole appeared mostly flat and perpendicular to the fracture surface, but gradually changed to a slant plane closer to the fastener hole in the lower flange, where the fracture intersected the inboard side of the fastener hole. Forward of the fastener hole, flat fracture features were observed in a plane perpendicular to the Z-stringer surface, features consistent with fatigue.

In order to separate the skin cracks, the skin was cut with snips to within approximately 0.1 inch of the crack tip, and as the cut was finished, the remaining ligament fractured. The crack surfaces were mostly covered with a black deposit. The inboard sides of the crack surfaces were cleaned using acetone and a brush followed by ultrasonic cleaning in soapy water. A view of the inboard side of the crack surfaces and the fastener hole bore after cleaning is shown in figure 10, and closer views of the surfaces aft and forward of the fastener hole are shown in figures 11 and 12, respectively. The crack surfaces were relatively flat and perpendicular to the skin surface, features consistent with fatigue. The extent of the fatigue regions are indicated with unlabeled brackets in figures 11 and 12. Aft of the fastener hole, the fracture features were mostly covered with black deposits as shown in figure 11. However, a curving crack arrest line was visible at the fatigue boundary at the aft end of the fatigue region. Forward of the fastener hole, fine fracture features were mostly obliterated by post fracture corrosion and rubbing damage. Corrosion pitting through approximately 20 percent of the thickness was observed locally at the crack location aft of the fastener hole shown in figure 12.

Samples from one of the repair angles were cut to facilitate measurements of hardness, conductivity, and composition. Samples were sanded by hand to remove paint and the clad layer, and the remaining thickness was 0.038 in the areas measured for hardness. Hardness was 66.5 HRB, lower than a typical value of 74.5 HRB listed in the *Aerospace Structural Metals Handbook*[1] for the 2024-T3 alloy specified for the repair. Conductivity was 33.4 percent IACS. The typical value for conductivity of 2024-T3 listed in the *Aerospace Structural Metals Handbook* is 29.7 percent IACS.

Composition of the repair angle material as measured using an optical emission spectrometer was aluminum with 4.36 percent copper, 1.35 percent magnesium, 0.55 percent manganese, 0.29 percent iron, 0.08 percent silicon, 0.09 percent zinc, 0.02 percent titanium, and 0.01 percent chromium. Among all other elements tested, including calcium, lead, nickel, tin, cobalt, bismuth, cadmium, boron, beryllium, strontium, vanadium, gallium, silver, and zirconium, all had individual percentages less than 0.04 percent and the total percentage of these other elements was less than 0.01 percent. Composition was within limits listed in the *Aerospace Structural Metals Handbook* for 2024 aluminum alloy.

Each of the three Z-stringers at the lower side of the wing box beam had four slosh holes in their webs for a total of 12 slosh holes. The holes were located one inch outboard of right WS 34, one inch outboard of right WS 48, one inch outboard of left WS 34, and one inch outboard of left WS 48.

The rear Z-stringer was fractured at three of its four slosh holes, all but the slosh hole just outboard of left WS 48. Fatigue features were observed emanating from the slosh holes in the three locations where the rear Z-stringer fractured at the slosh holes as documented in *Materials Laboratory Factual Report 06-010* and earlier in this report. Sealant was cleaned from around the rear Z-stringer slosh hole just outboard of left WS 48 using acetone and a wooden tongue depressor. The cleaned hole was examined using a stereo microscope, and no evidence of cracks was observed.

None of the fractures in the center Z-stringer intersected a slosh hole. Sealant around all four slosh holes was removed using acetone and a wooden tongue depressor. The cleaned holes were examined using a stereo microscope, and no evidence of cracks was observed.

In the forward Z-stringer, one fracture intersected the slosh hole just outboard of left WS 34. No other fractures in the forward Z-stringer intersected a slosh hole. As documented in *Materials Laboratory Factual Report 06-010*, the fracture features

[1] *Aerospace Structural Metals Handbook*, Edited by W. F. Brown, Jr., H. Mindlin, and C. Y. Ho, CINDAS/Purdue University (1995).

intersecting the slosh hole just outboard of left WS 34 were consistent with overstress fracture. Sealant was removed from the other three forward Z-stringer slosh holes using acetone and a wooden tongue depressor. The cleaned holes were examined using a stereo microscope, and no evidence of cracks was observed.

Matthew R. Fox
Senior Materials Engineer

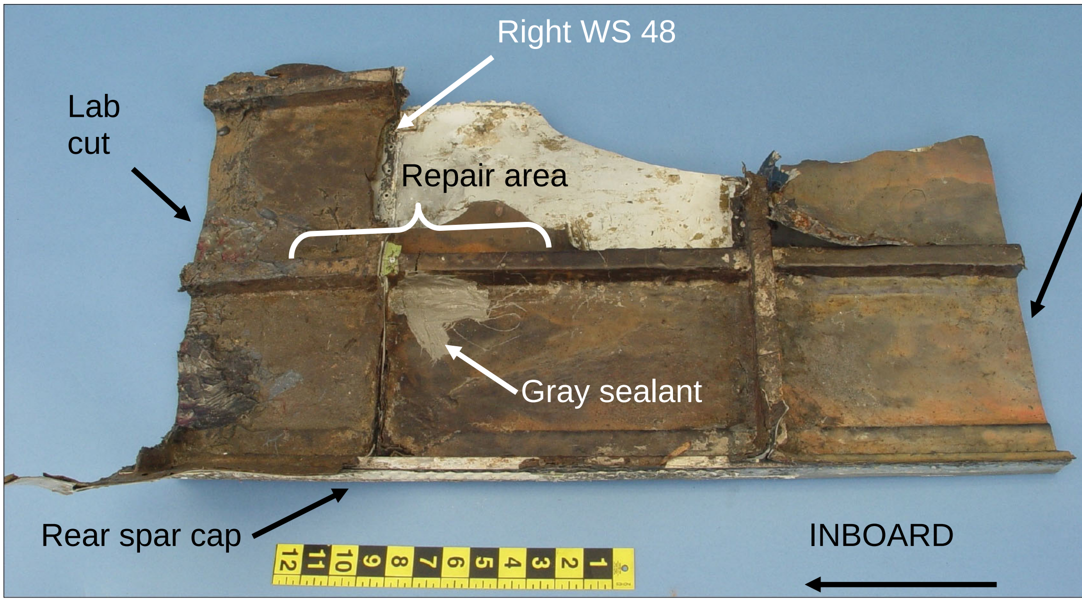

Image No.:0605A00091, Project No.: 2006050002

Figure 1. Overall view of the interior surface of the wing box beam piece containing the rear Z-stringer repair at right WS 48.

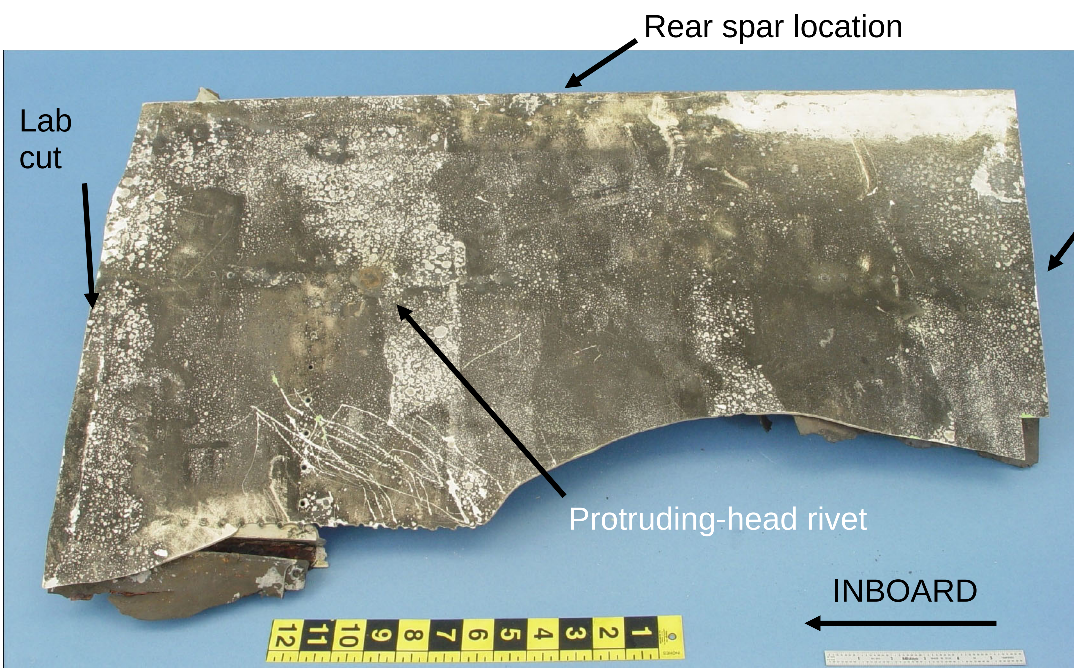

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Figure 2. Overall view of the exterior surface of the wing box beam piece containing the rear Z-stringer repair at right WS 48. The protruding-head rivet was located near the center of the repair area.

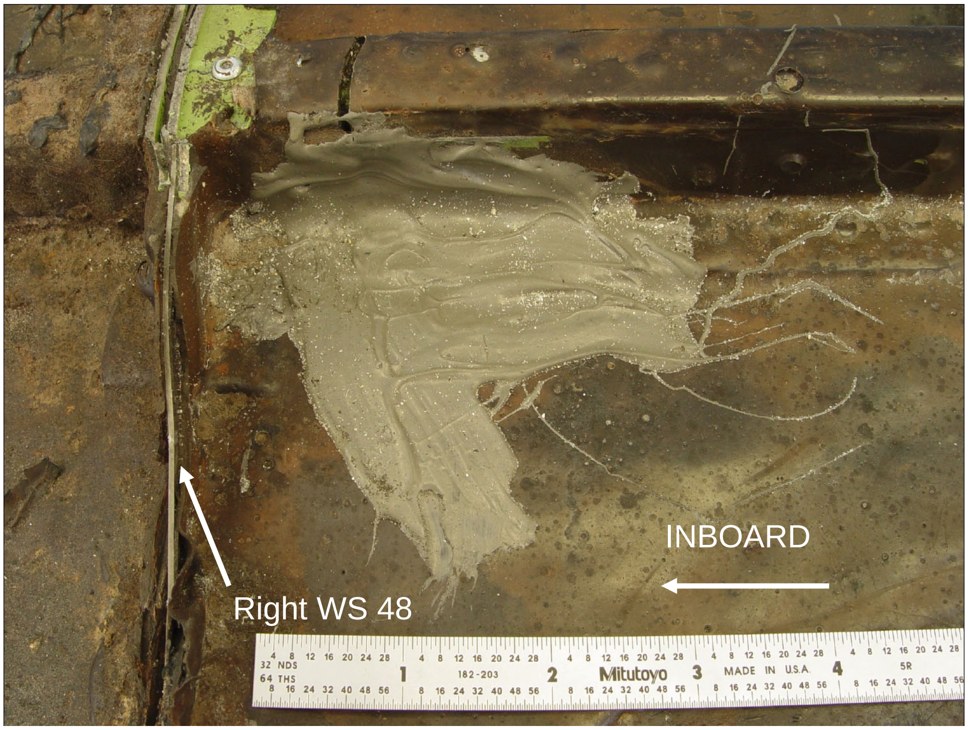

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Figure 3. Closer view of the gray sealant shown in figure 1.

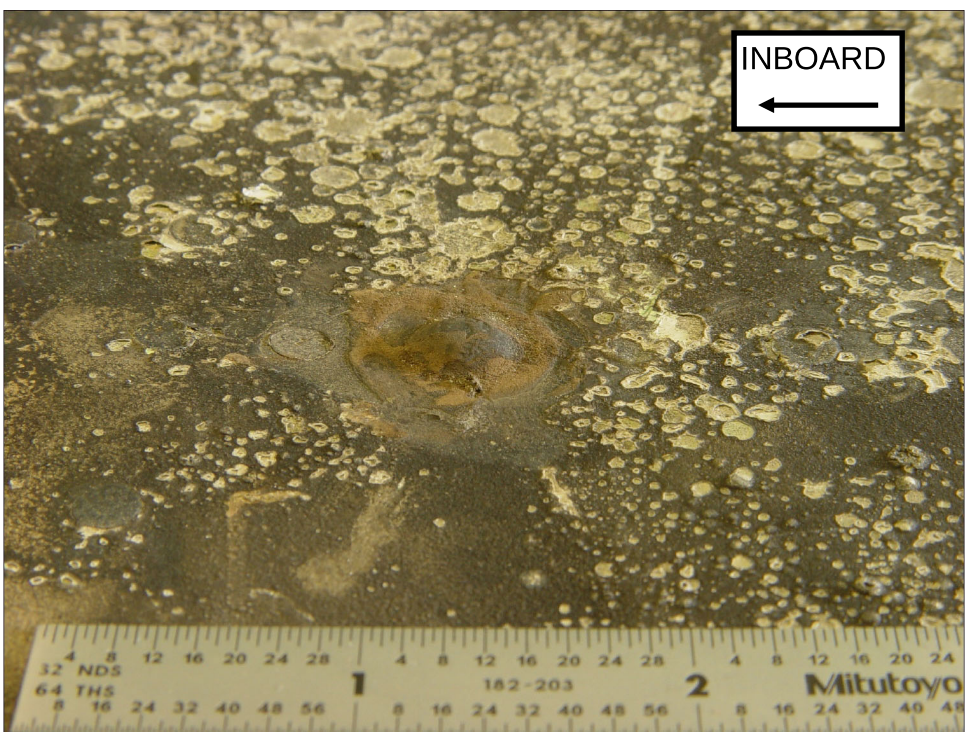

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Figure 4. Closer view of the protruding-head rivet indicated in figure 2.

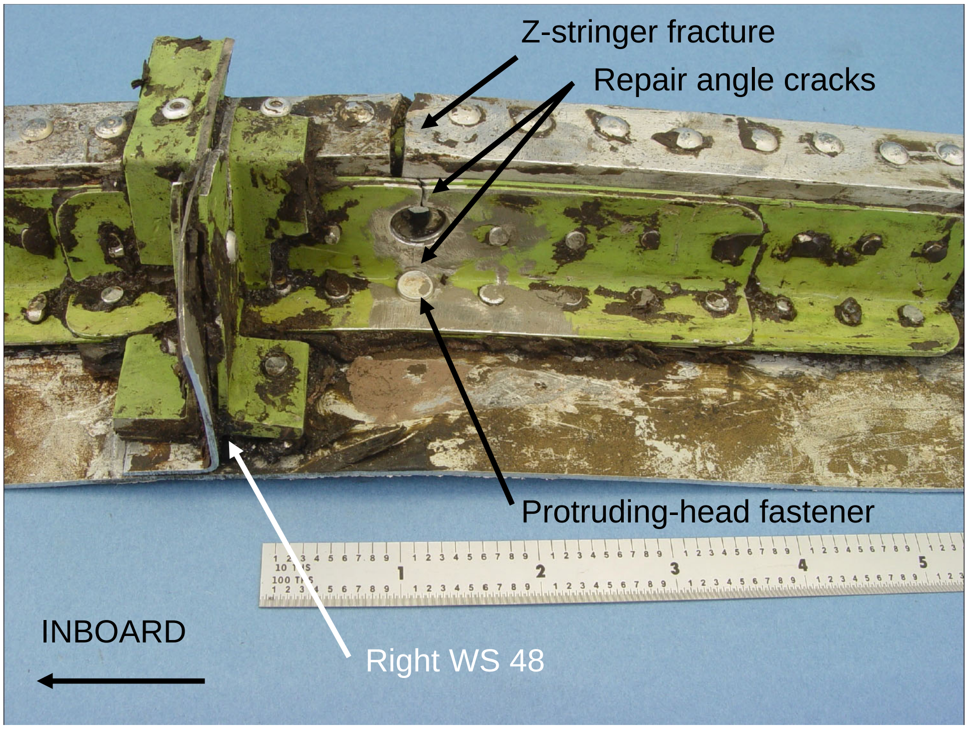

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Figure 5. View of the aft side of the rear Z-stringer repair after sealant removal.

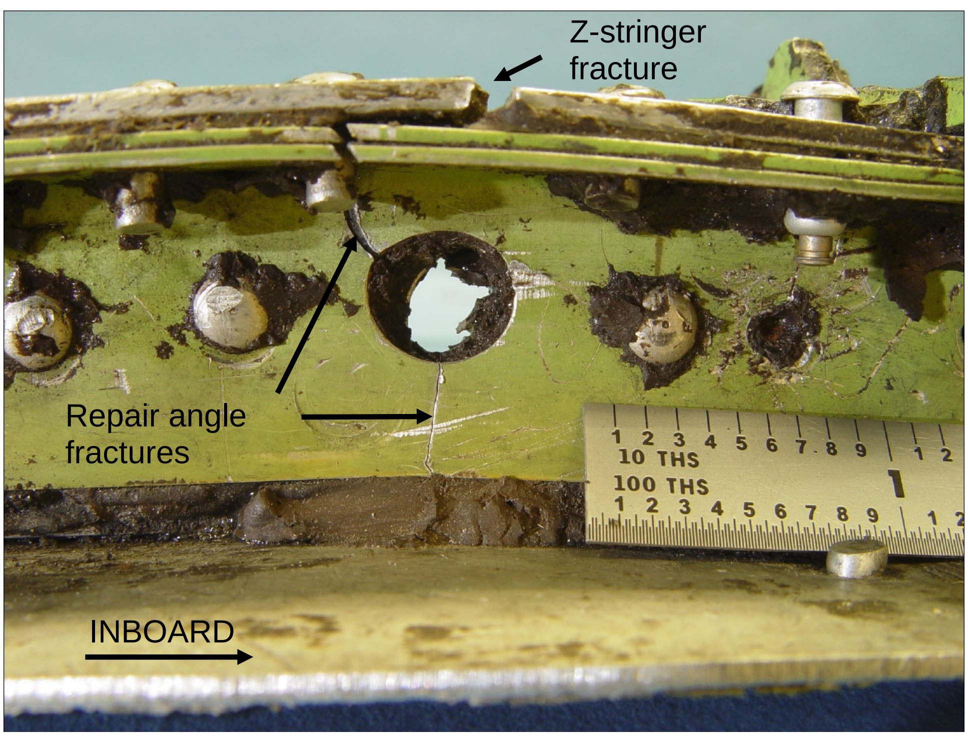

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Figure 6. Close view of the forward side of the rear Z-stringer repair at the slosh hole location after sealant removal.

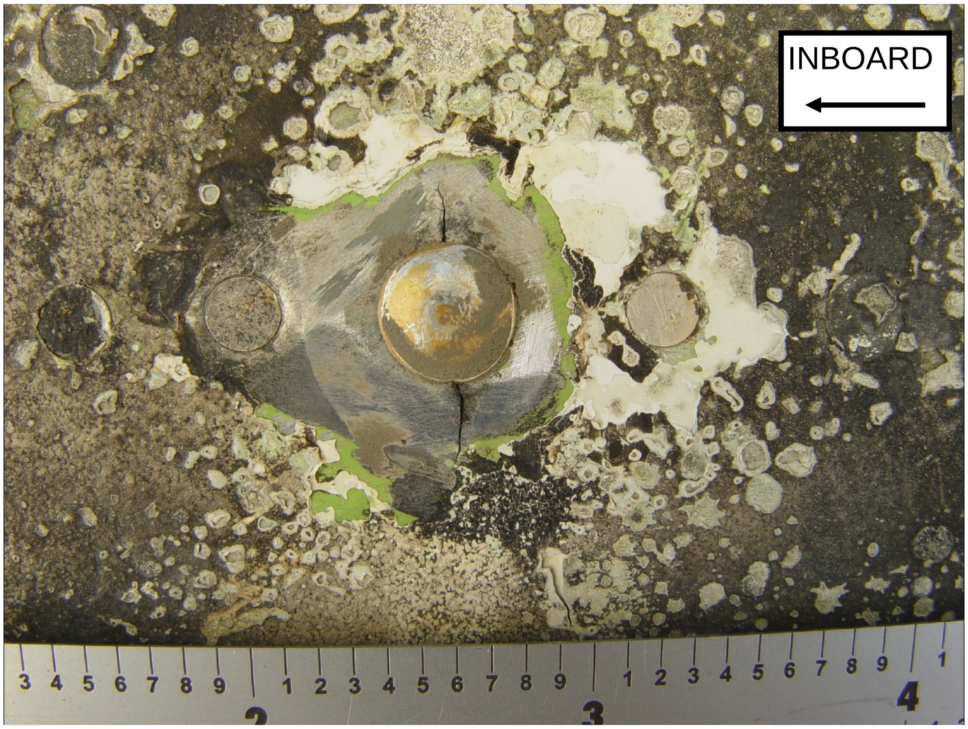

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Figure 7. View of the protruding-head rivet shown in figure 4 after cleaning and sealant removal with acetone and a brush.

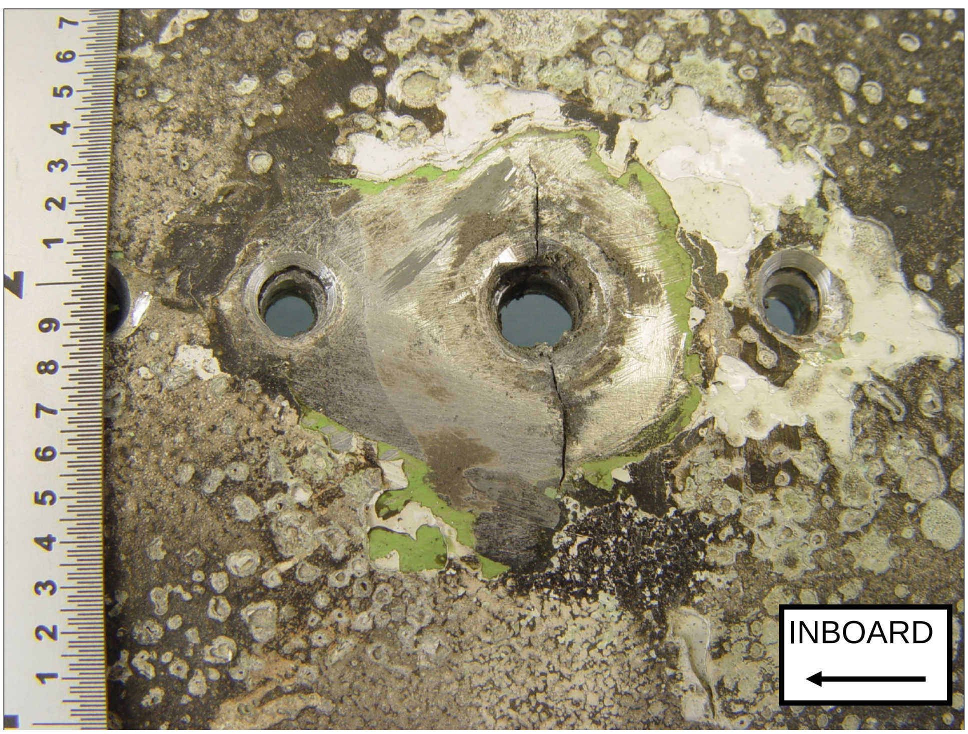

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Figure 8. View of the skin lower surface in the area shown in figure 7 after fastener removal.

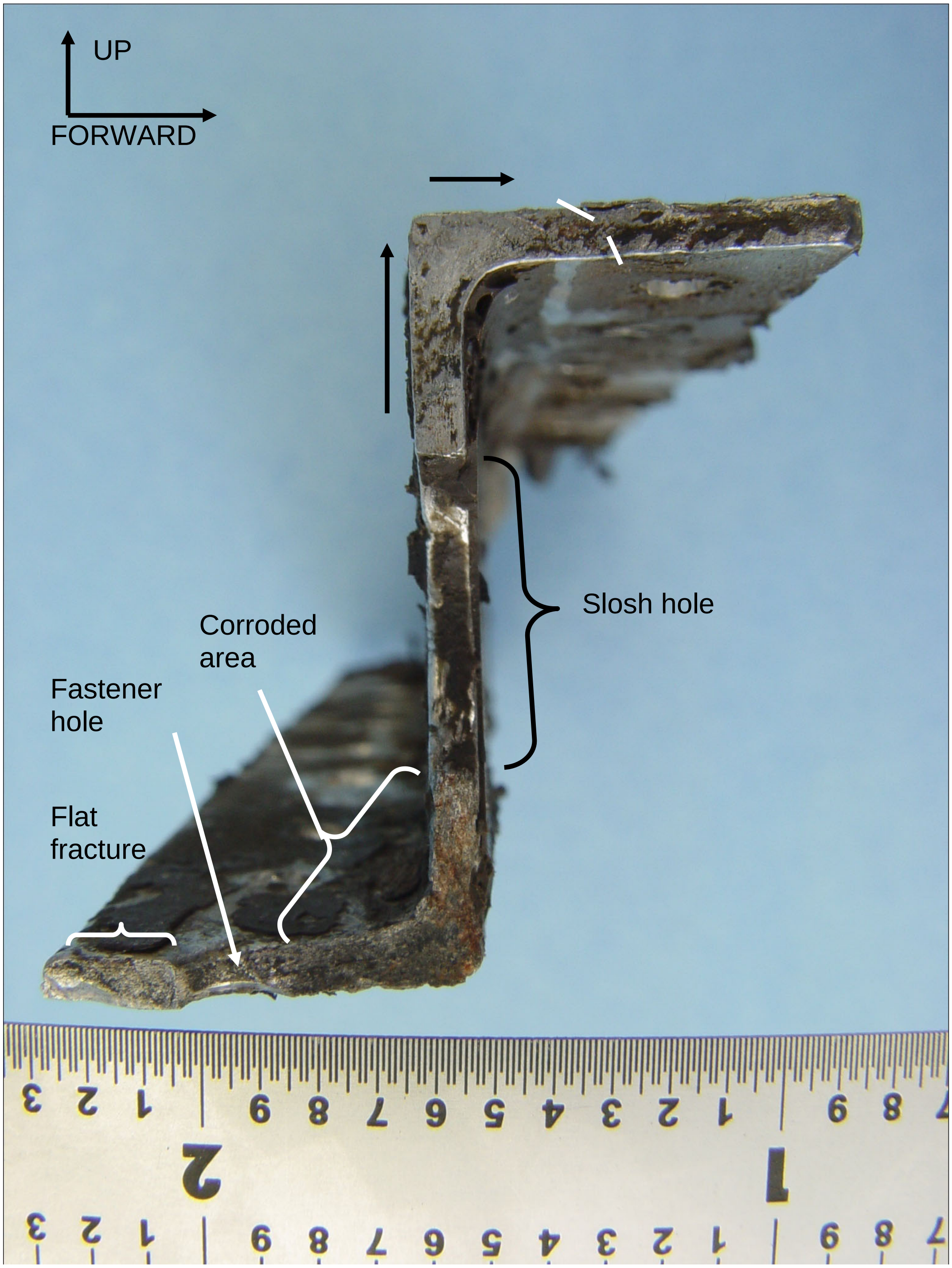

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Figure 9. View of the inboard surface of the rear Z-stringer fracture after removal of repair angles and cleaning with soapy water and a brush. The dashed line at the upper flange indicates the boundary of the fatigue region emanating upward from the slosh hole.

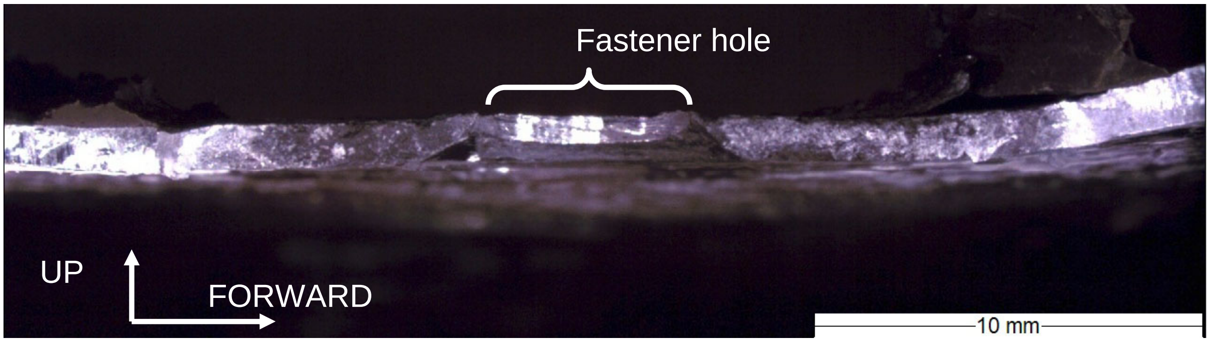

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Figure 10. View of the skin inboard side of the skin crack surfaces after opening the cracks and cleaning with soap water, acetone, and a brush.

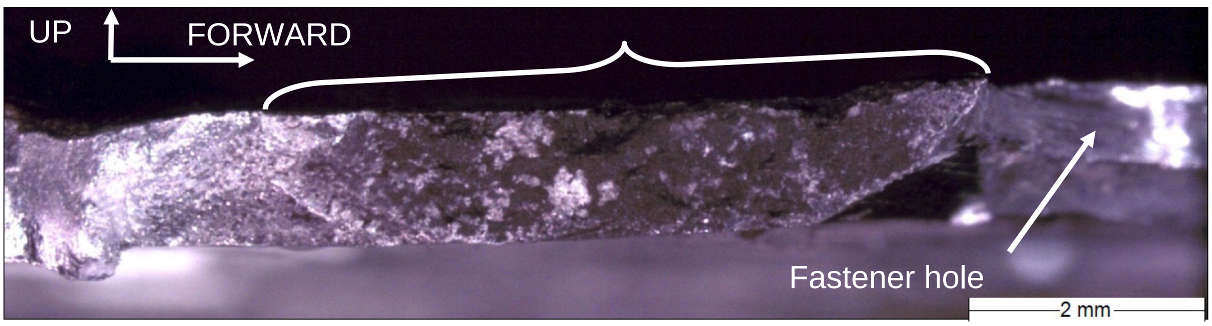

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Figure 11. Closer view of the crack surface aft of the fastener hole. An unlabeled bracket indicates the extent of the flat fracture region perpendicular to the skin surface.

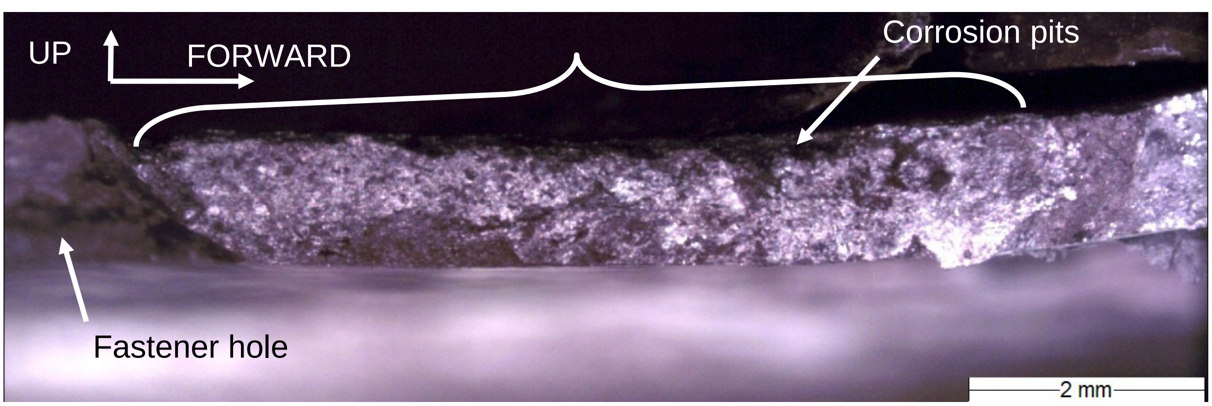

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Figure 12. Closer view of the crack surface forward of the fastener hole. An unlabeled bracket indicates the extent of the flat fracture region perpendicular to the skin surface.