

NATIONAL TRANSPORTATION SAFETY BOARD

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



March 23, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 17-094

A. ACCIDENT INFORMATION

Place : Harvard, Illinois
Date : November 8, 2017
Vehicle : Cessna 170
NTSB No. : CEN18LA044
Investigator : Jennifer Rodi

B. COMPONENTS EXAMINED

1. Portions of a McFarlane Aviation, Inc universal joint assembly model MC0411257 (JO#43600).
2. Exemplar McFarlane Aviation, Inc universal joint assembly model MC0411257 (JO#43600).

C. DETAILS OF THE EXAMINATION

An exploded diagram of the universal joint is shown in Figure 1, with each key component labelled. The exemplar universal joint and the incident universal joint pieces are shown in Figure 2. Figure 2b shows labels for each key feature identified on the incident universal. For report purposes, each yoke ear has been given a unique identifier. As received, the incident universal pieces were visually examined using a 5X to 50X stereo-zoom microscope for the presence of a light oil lubricant. No lubricant film was observed on any surface.

Figure 3 is an image the vertical yoke portion of the incident universal, with the swivel block and the center pin installed. The key features are labelled in the image. As received, the swivel block could be rotated about the center pin. Hand-applied torque of close-fitting gage pin installed in the cross-drilled hole in the center pin revealed that the center pin could not be rotated about its main axis. Closer views of the wear scars on the flat sides of the swivel block that were in contact with the faying surfaces of the HY_{ear 1} and HY_{ear 2} ears on the horizontal yoke are shown in Figures 4 and 5. The wear scars, when viewed under a 50X stereo-zoom microscope, exhibited fine excrescence¹ features associated with incipient galling and material loss and transfer associated with adhesive wear. The scars were primarily oriented +/- 11° from the long axis of the universal. Closer views of the flat features on the center pin are shown in Figure 6. The flats on the center

¹K. G. Budinski, *Friction, Wear, and Erosion Atlas*, CRC Press, Boca Raton, FL, 2017, pg. 13.

pin exhibited adhesive wear scars and the exposed round surfaces of the center pin exhibited particulate wear debris consistent with adhesive wear.

Overall views of the half pins are shown in Figures 7 and 8. The half pin in Figure 7 has a portion of the rivet. The rivet piece exhibited a transverse fracture through the thickness. The outside diameter surfaces of the half pins exhibit material loss and wear debris deposits. The ends of the half pins that contact the center pin flats exhibit a modicum of adhesive wear. Top-down views of the fracture surface in the rivet shank is shown in Figures 9-13. As identified in the annotated image in Figure 11, the rivet shank fractured due to fatigue crack propagation from two crack advancing cracks, initiating approximately 180° from each other, consistent with reversed bending fatigue. A small region at the neutral axis fractured in overstress. As indicated in Figure 11, there are regions of mechanical damage associated with the origin regions of the two fatigue cracks, consistent with reversed bending of the rivet shank within the assembly.

Ear VY_{ear 1} was cut from the horizontal yoke as indicated in Figure 14. After cutting, the swivel block, center pin, and ear VY_{ear 1} could be removed from the horizontal yoke subassembly as the center pin could be directly slid from ear VY_{ear 2}. The center pin portion that mated with VY_{ear 2} exhibited wear debris and material loss consistent with adhesive wear (see Figures 15 and 16). The hole in VY_{ear 2} exhibited similar adhesive wear scars and wear debris deposits.

Ear VY_{ear 1} would not spin freely about the center pin with any amount of hand force. To reveal the surface condition of the center pin in the ear VY_{ear 1} hole, the ear and center pin were longitudinally cross-sectioned to allow the two halves of the VY_{ear 1} ear to be removed (see Figures 17 and 18). The center pin portion that mated with VY_{ear 1} exhibited wear debris, material loss and excrescence features consistent with adhesive and galling wear. The hole in VY_{ear 1} exhibited similar adhesive and galling wear scars and wear debris deposits (see Figure 19).

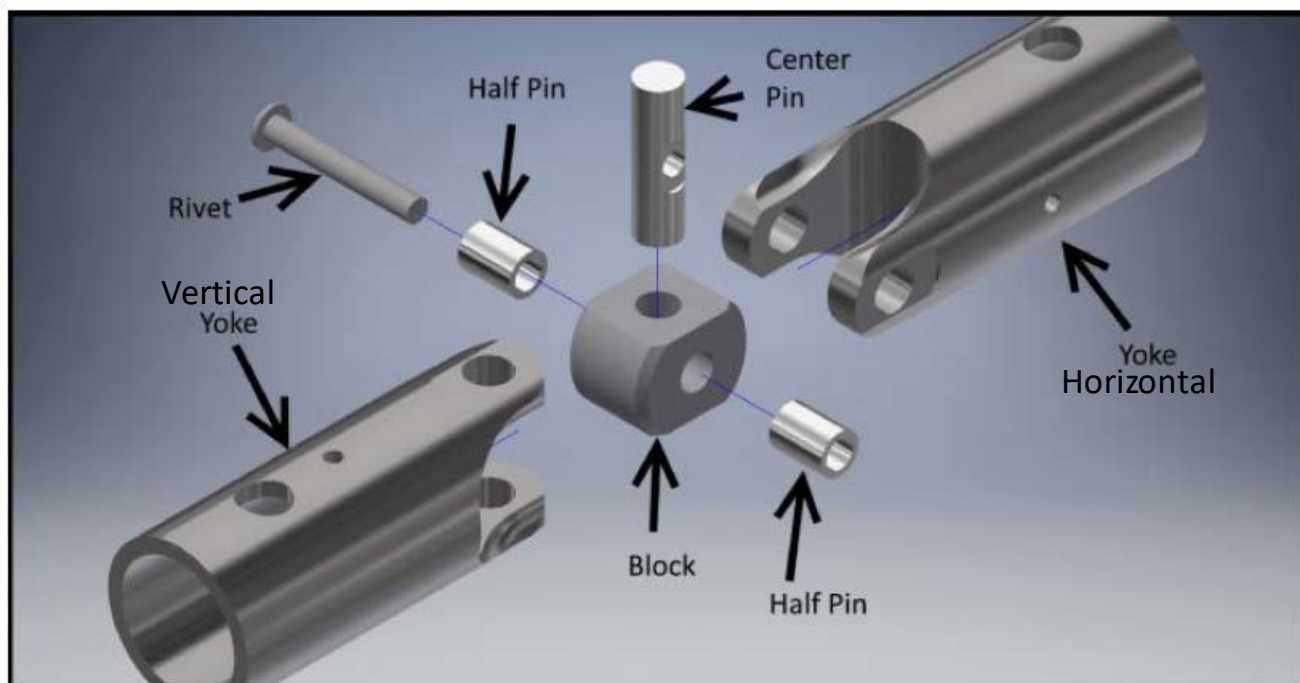
The alloy compositions for all pieces from the incident universal were confirmed using a Thermo Scientific Niton XL3t-980 x-ray fluorescence (XRF) alloy analyzer. The yokes, center pin, half pins, and swivel block are fabricated from type 17-4PH stainless steel—in accordance with engineering drawing specifications. The rivet piece is fabricated from type 304 stainless steel—in accordance with engineering drawing specifications.

For reference purposes, the hardnesses of the yokes, swivel block, and the center pin were measured in accordance with ASTM E18-17. The average results are listed below.

Component	Hardness (HRC)
Vertical yoke	41.5
Horizontal yoke	42.7
Swivel block	42.9
Center pin	41.6

The exemplar universal passed the free-rotation, half-pins rotation, and center pin rotation functionality tests as outlined in the McFarlane Aviation, Inc. Service Bulletin SB-9 Revision A, December 11, 2017. No other tests were performed on the exemplar universal.

Michael Budinski
Chief, Materials Laboratory Division



McFarlane Aviation Inc., Service Bulletin SB-9
Revision A, December 11, 2017

Figure 1 Exploded parts diagram for the universal. Key components are labelled.

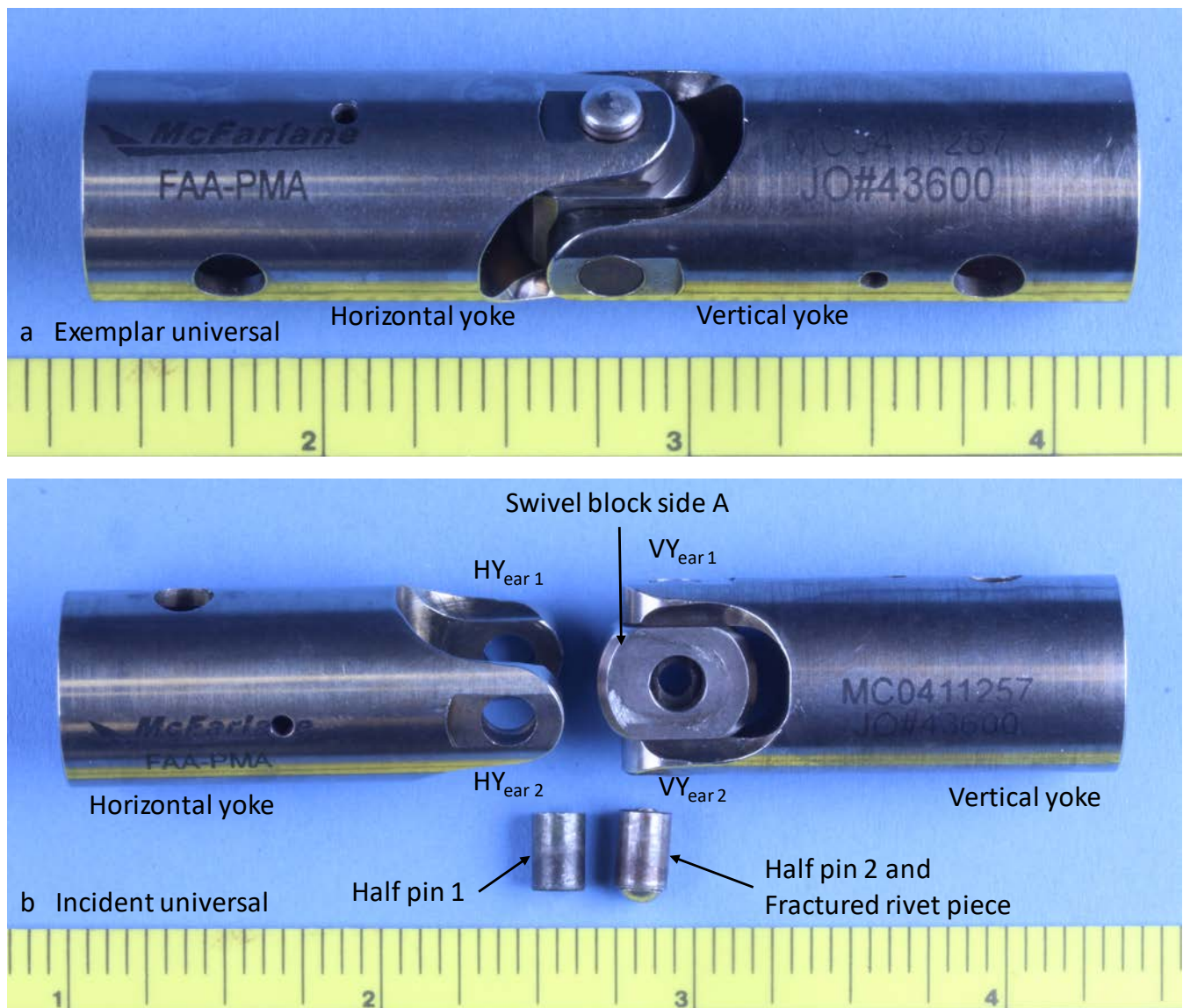


Figure 2 View a is an image of the exemplar universal. View b is an image of the pieces recovered from the incident universal.

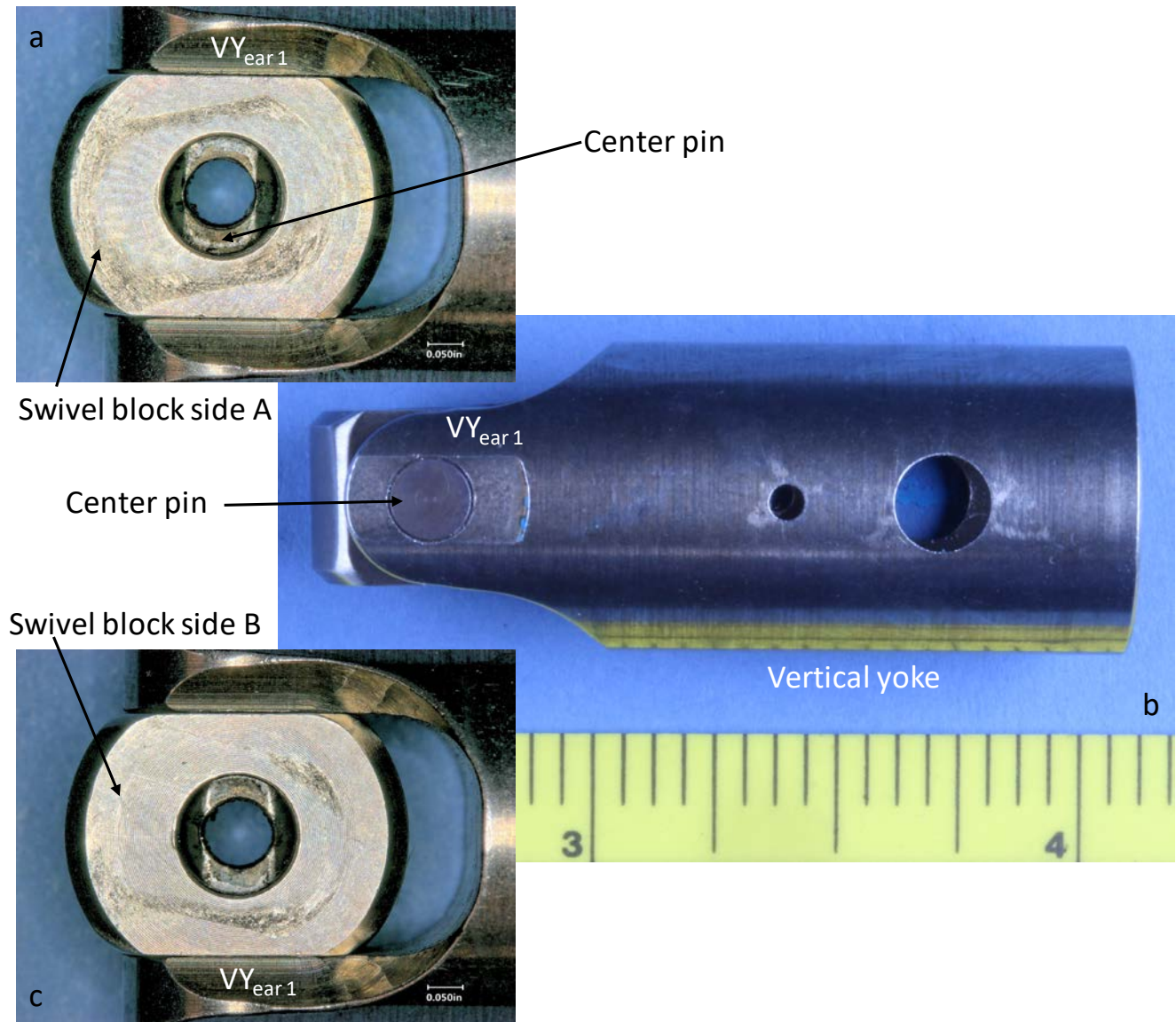


Figure 3 Views of the surfaces of the swivel block that contact the horizontal yoke ears. Closer views of the swivel block contact surfaces are shown in Figures 4 and 5.

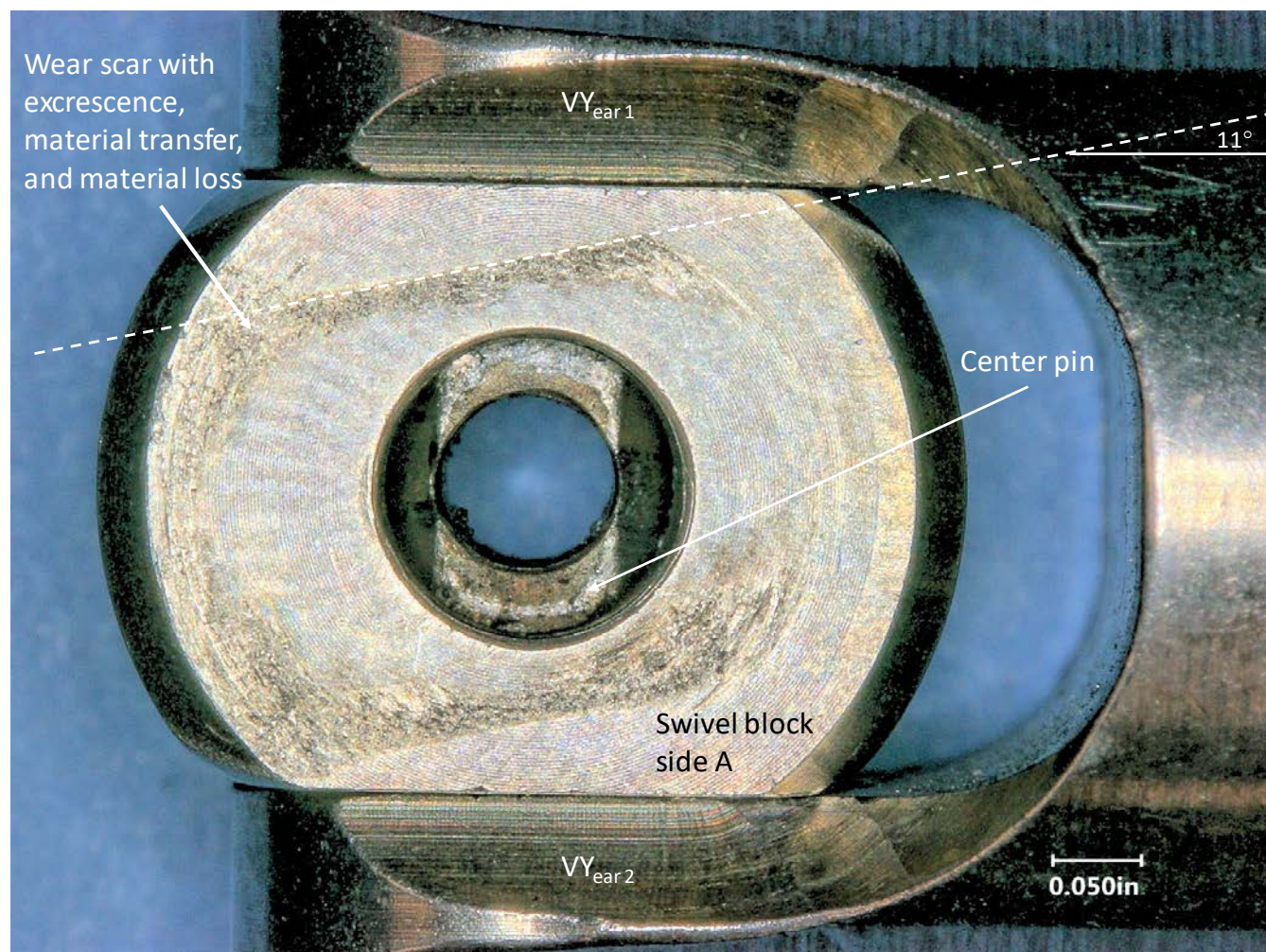


Figure 4 Closer view of the swivel block surface that contacts ear HY_{ear1}.

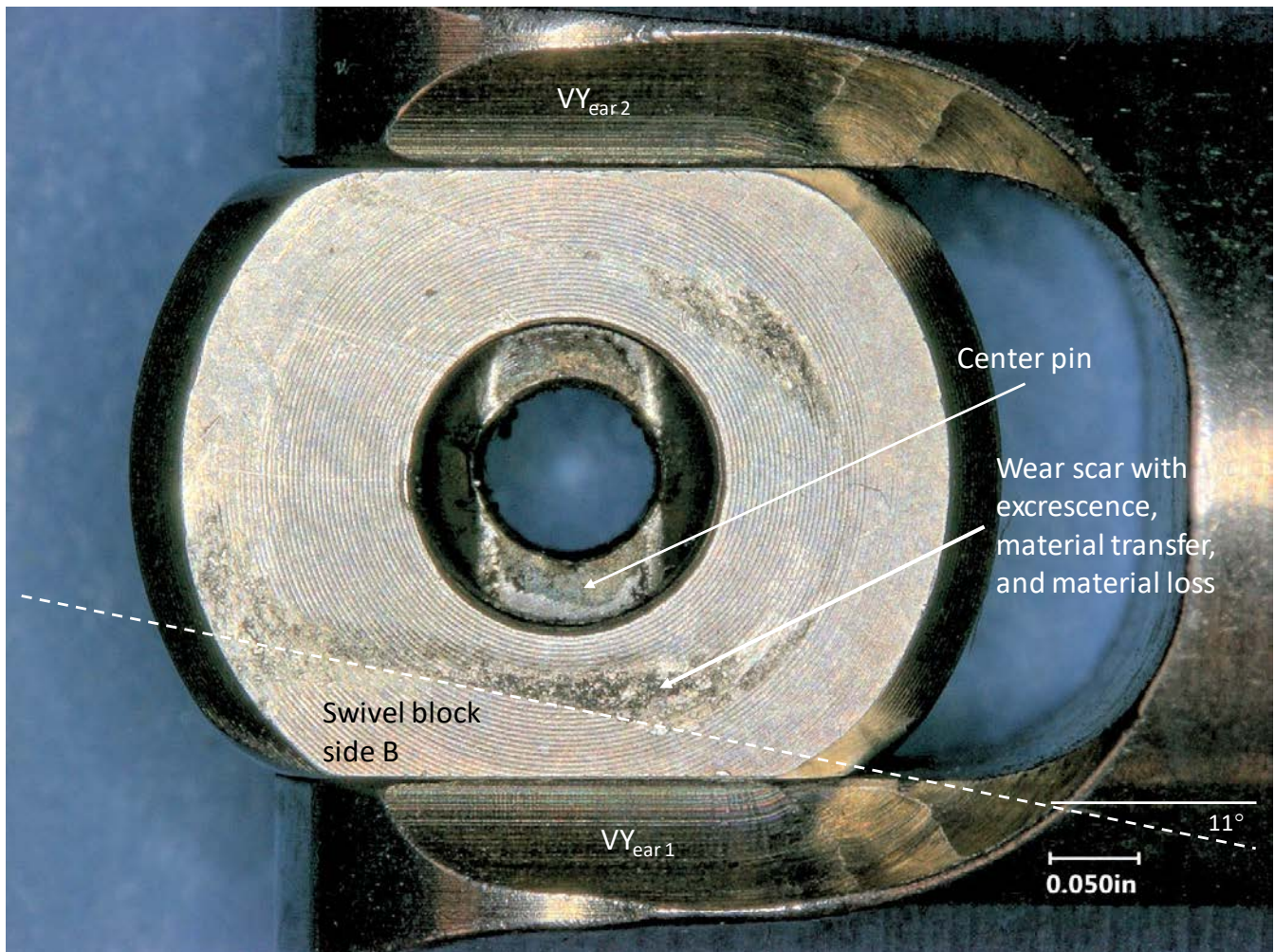


Figure 5 Closer view of the swivel block surface that contacts ear HY_{ear 2}.

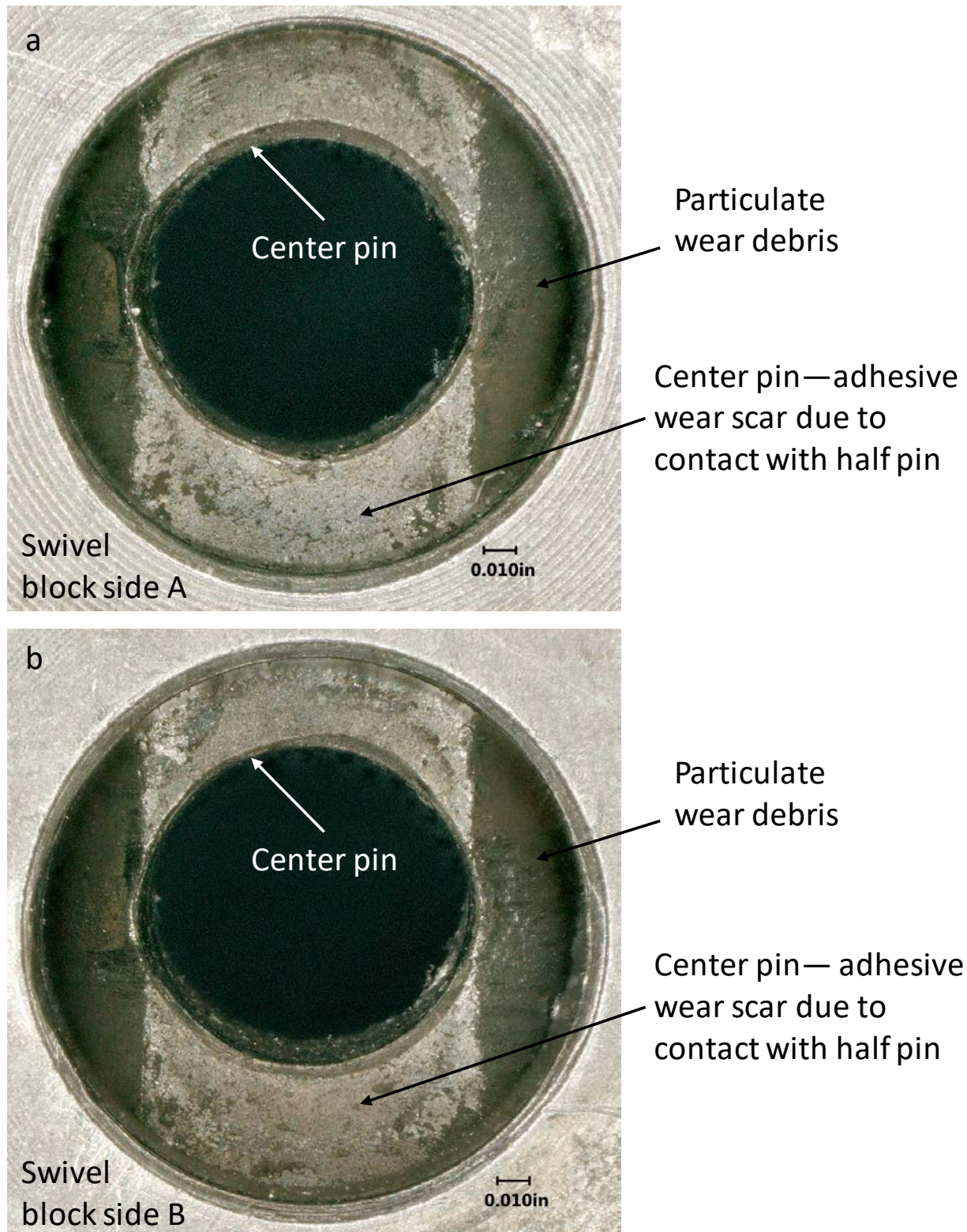


Figure 6 Closer views of the flat features on the center pin. The flats on the center pin exhibited adhesive wear scars and the exposed round surfaces of the center pin exhibited particulate wear debris.

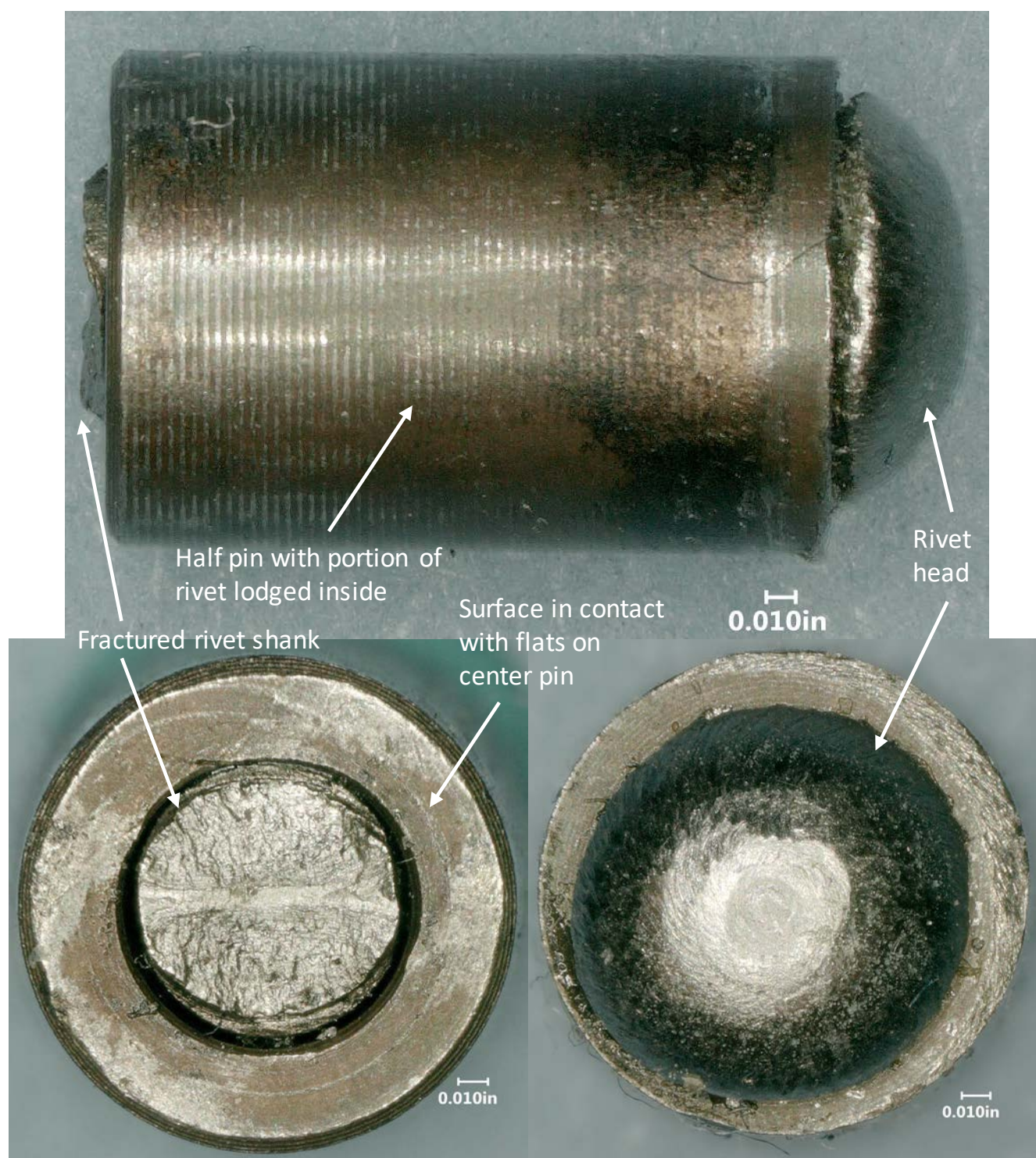


Figure 7 Three views of a half pin, recovered with a fractured portion of rivet.

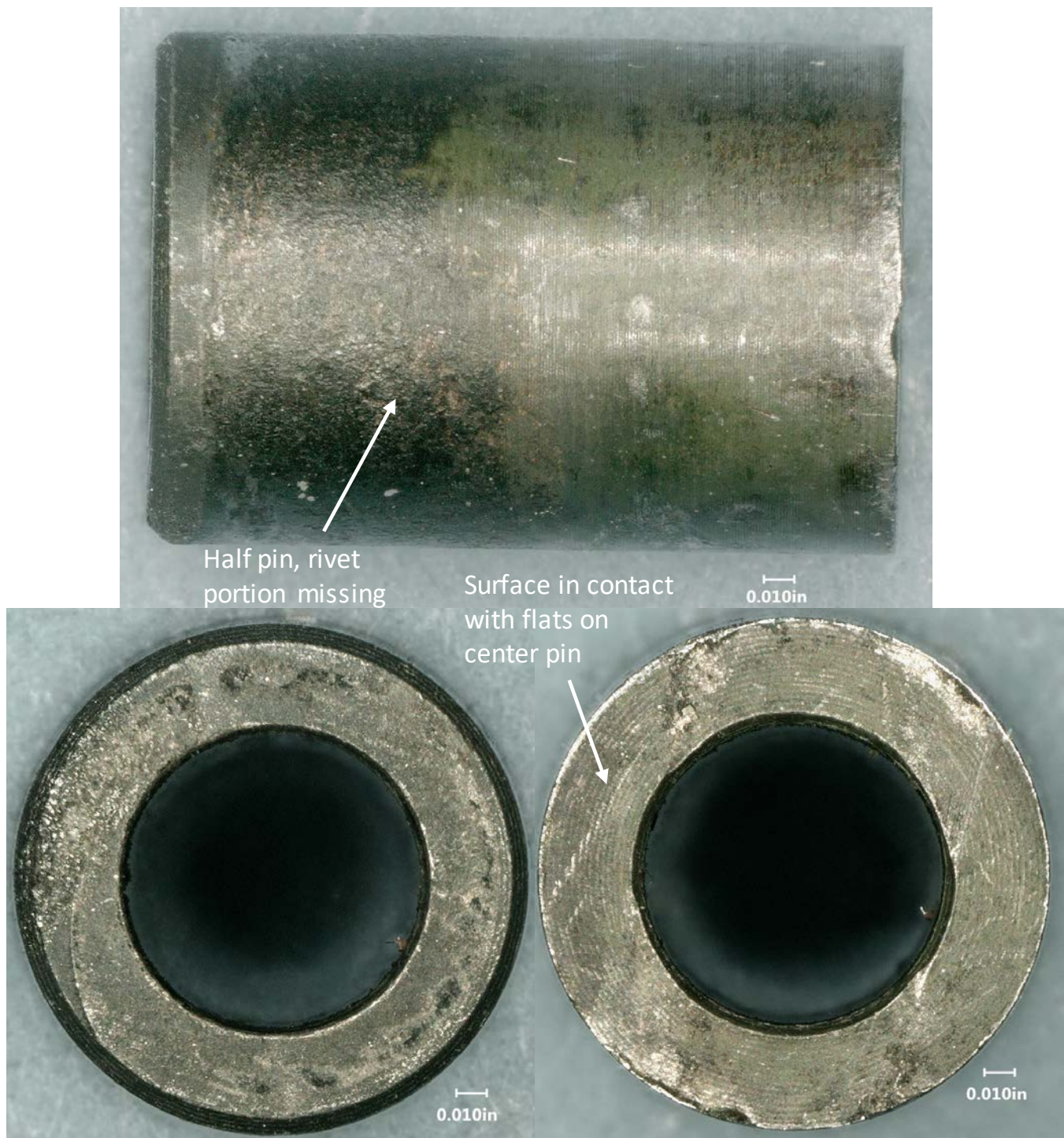


Figure 8 Three views of a half pin.

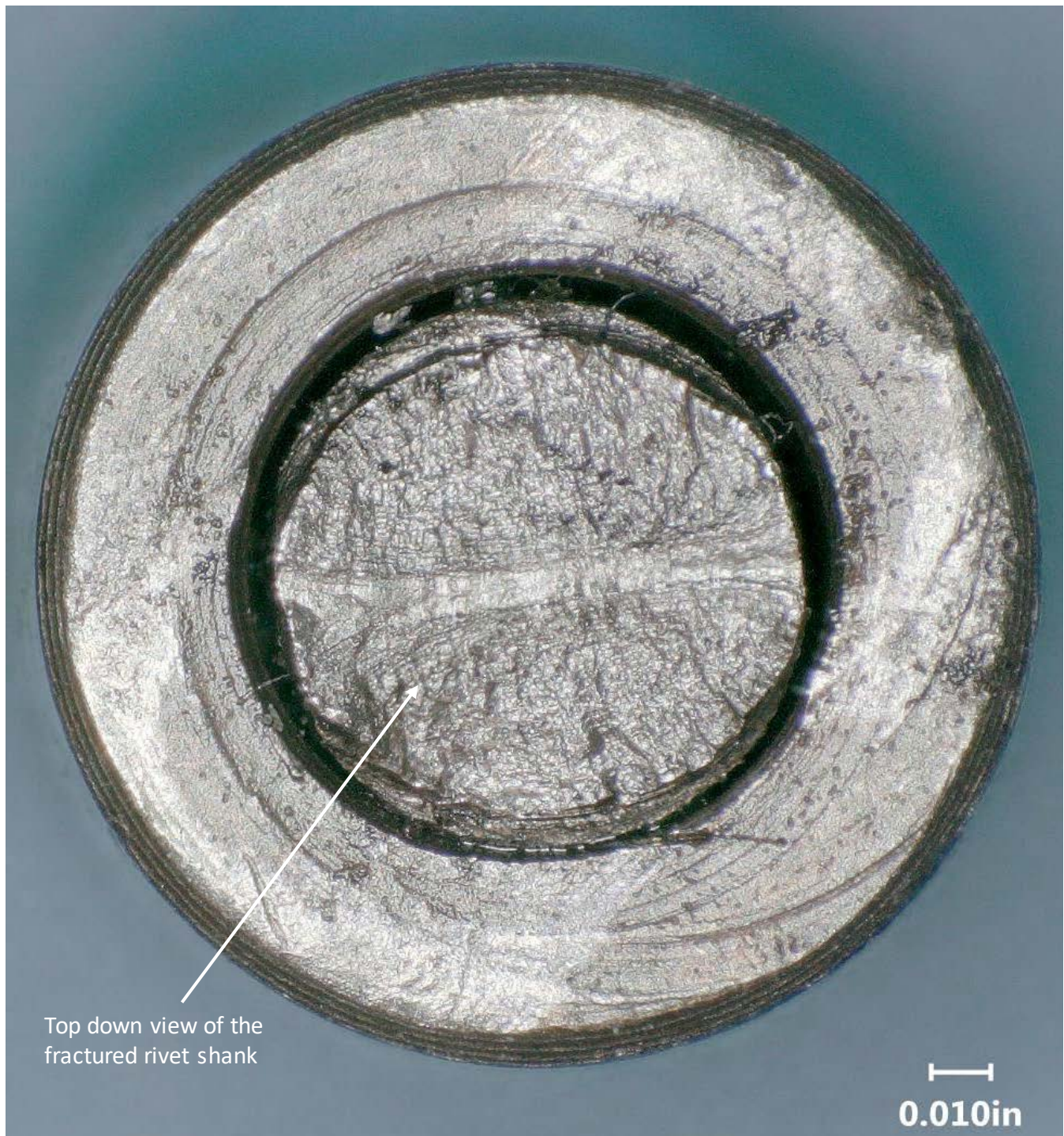


Figure 9 Digital microscope fractograph of the rivet shank fracture surface.

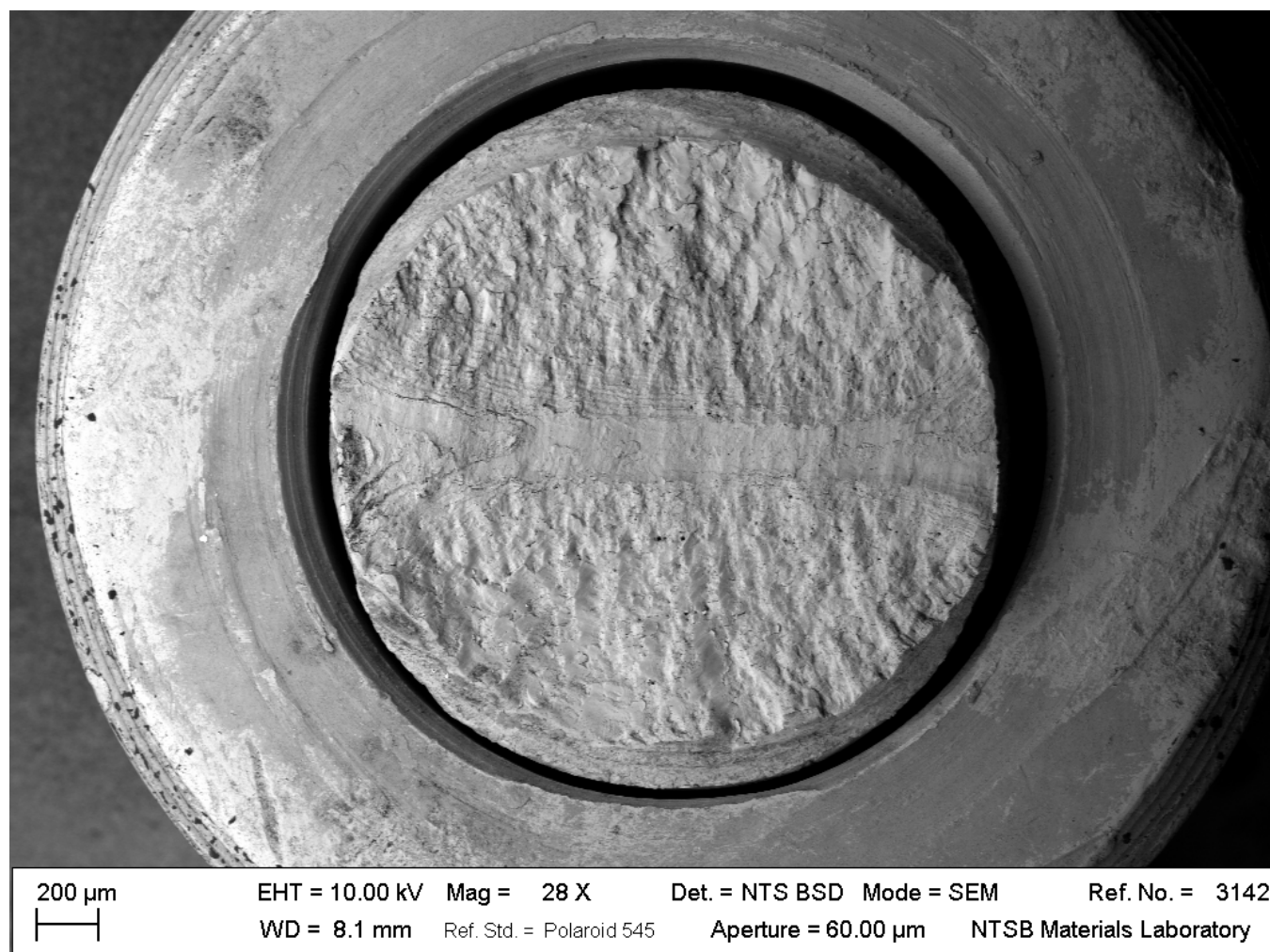


Figure 10 Backscatter scanning electron fractograph of the rivet shank fracture surface.

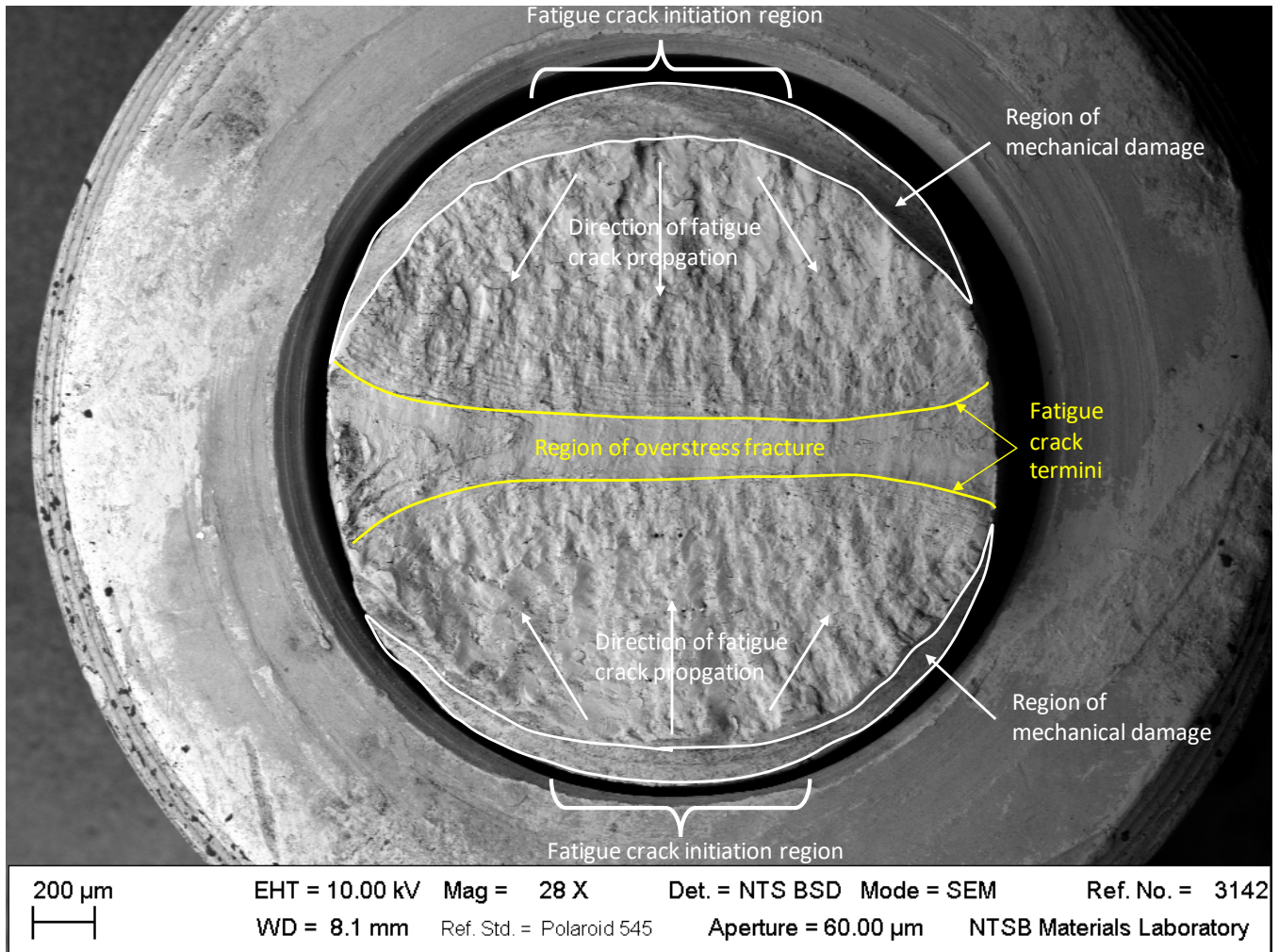


Figure 11 Backscatter scanning electron fractograph of the rivet shank fracture surface, annotated to identify key fracture surface features.

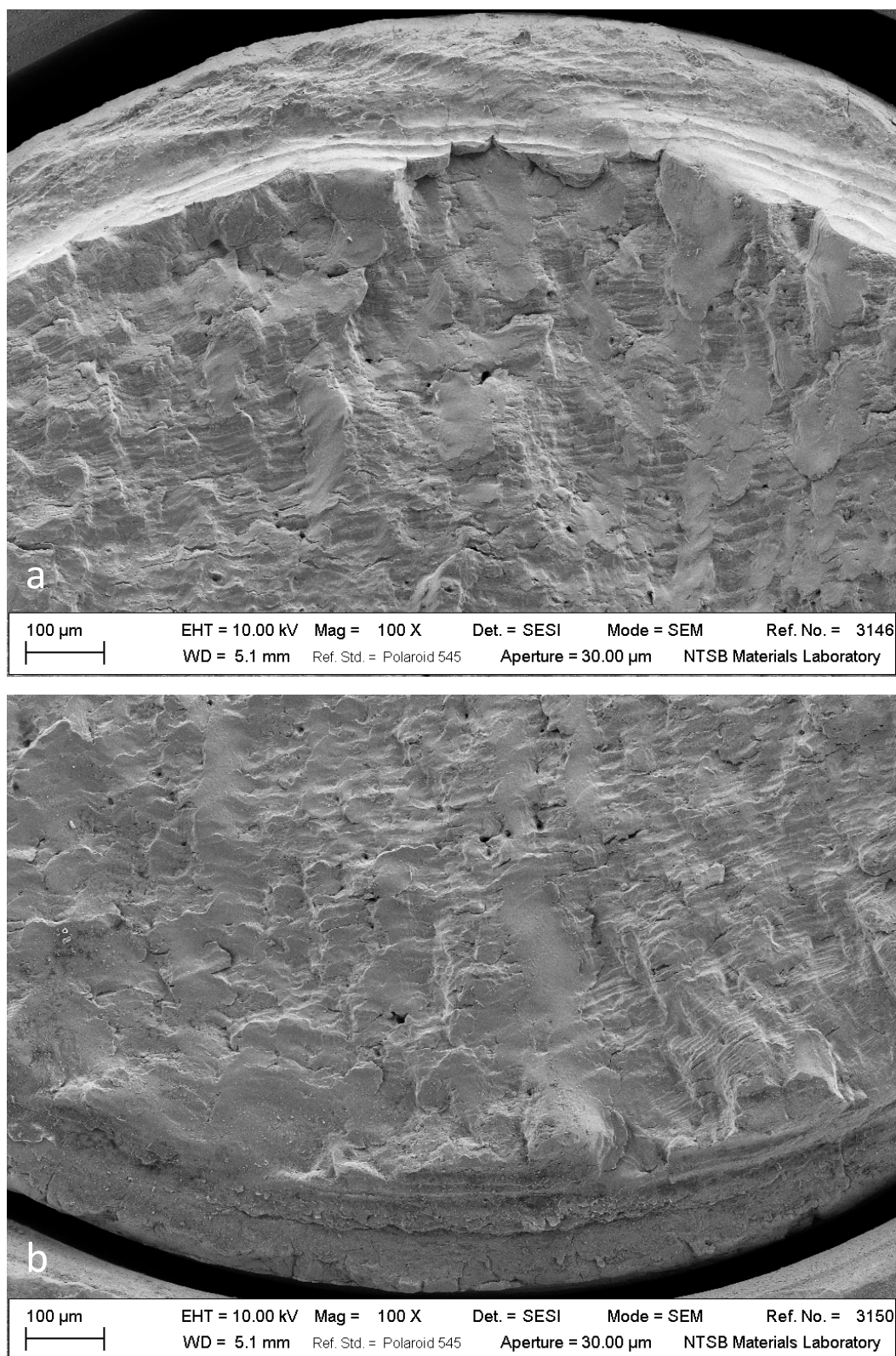


Figure 12 Secondary electron scanning electron fractographs of the two initiation regions identified in Figure 11.

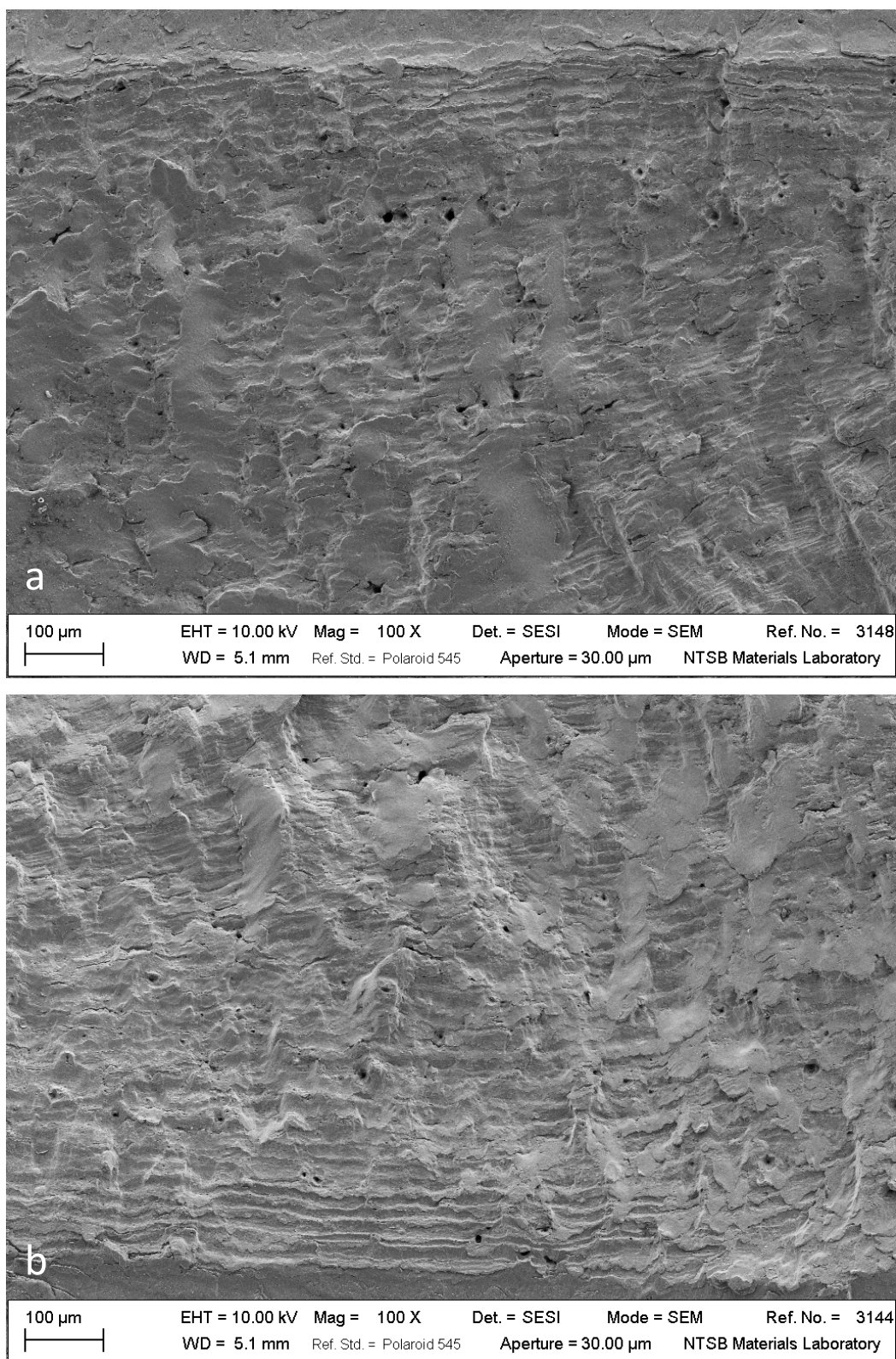


Figure 13 Closer secondary electron scanning electron fractographs of the two initiation regions identified in Figure 11.

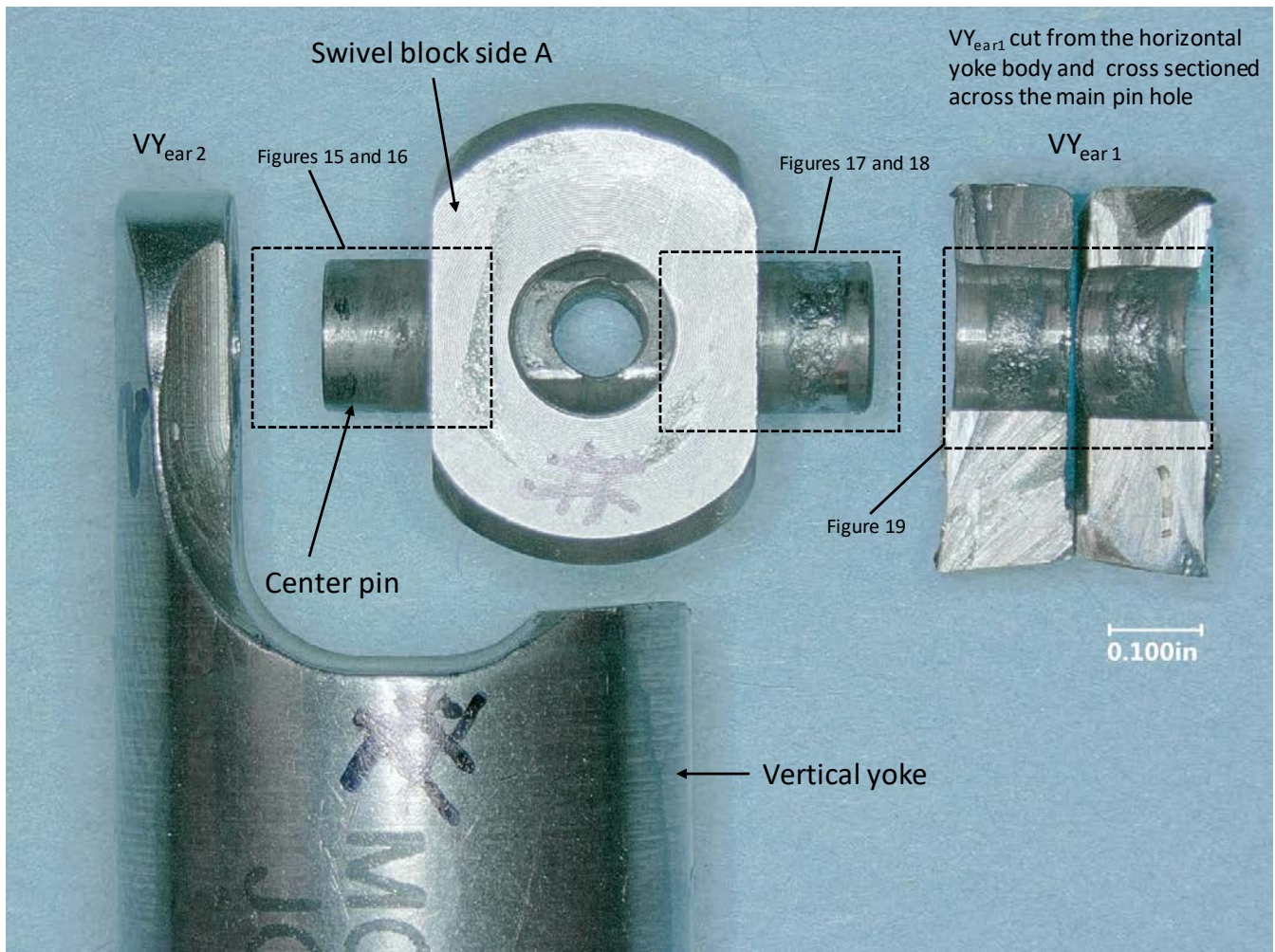


Figure 14 View of the swivel block and center pin sub-assembly as-removed from the vertical yoke assembly. Ear VY_{ear1} was transversely sectioned from the vertical yoke then cut longitudinally to reveal the surfaces of the cross-drilled hole and the center pin.

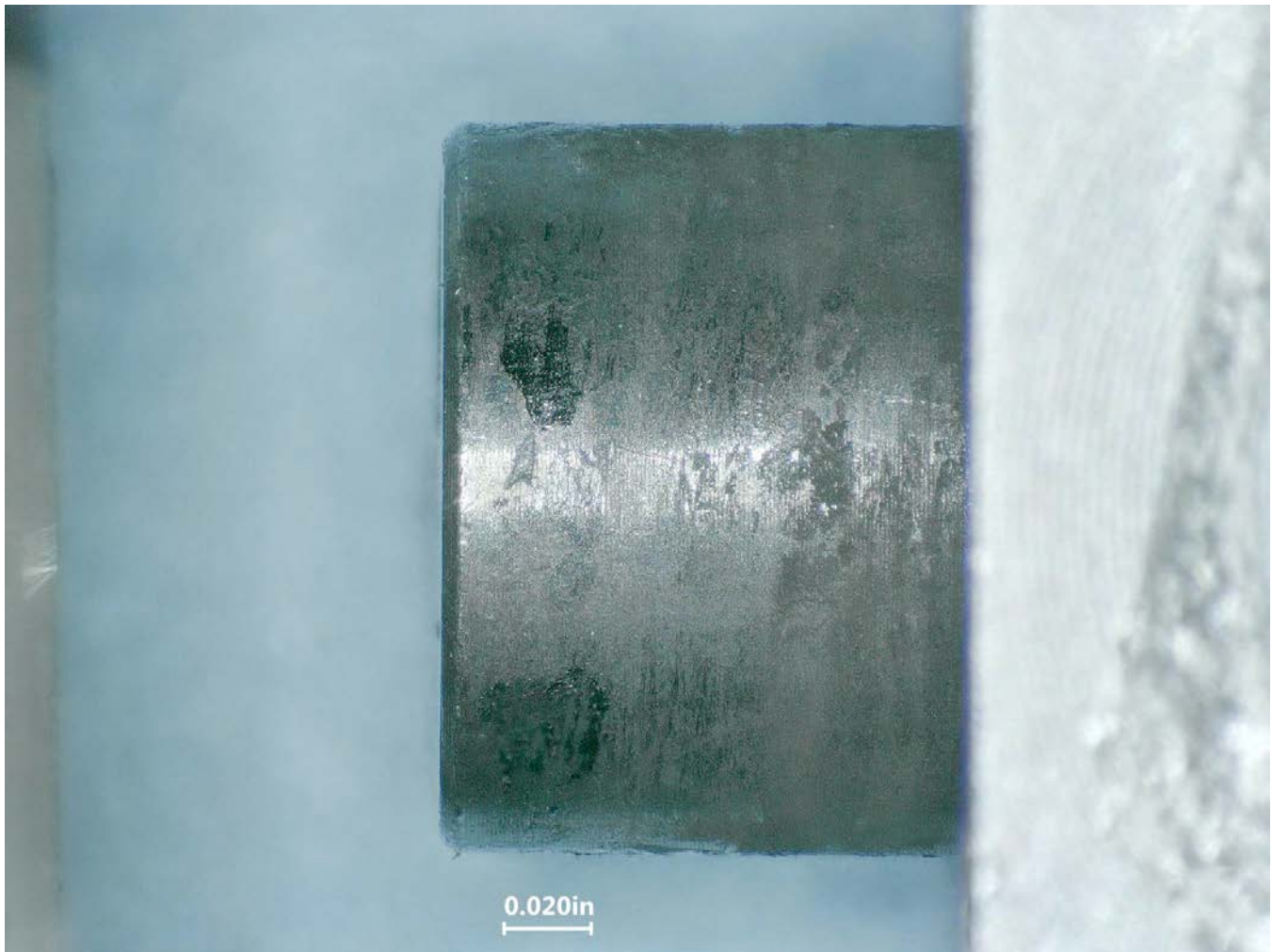


Figure 15 Digital microscope image of the center pin portion that is inserted into the cross-drilled hole in ear VY_{ear2} (see Figure 14).

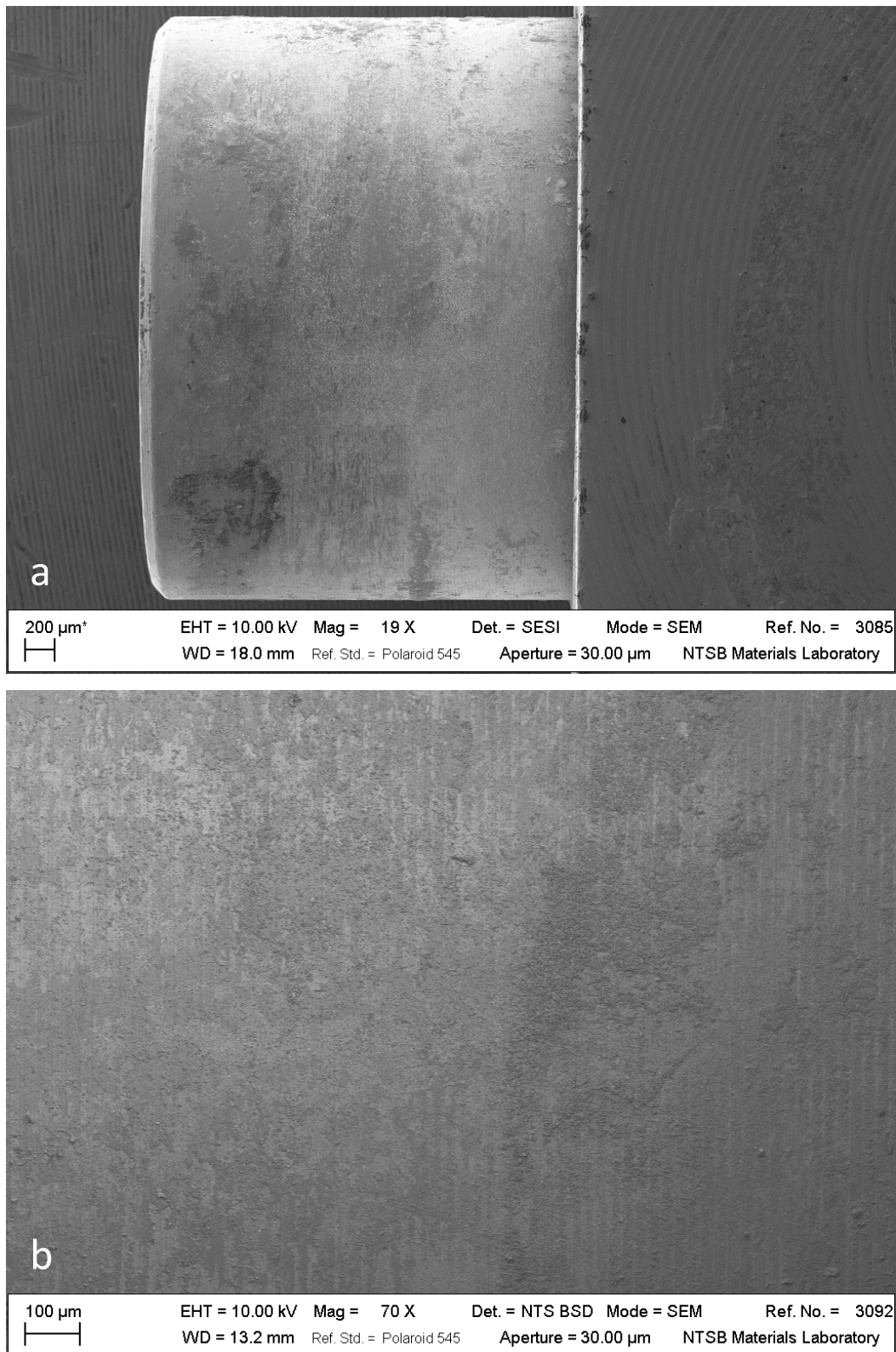


Figure 16 Secondary electron (view a) and backscattered electron (view b) scanning electron microscope images of the center pin portion that is inserted into the cross-drilled hole in ear VY_{ear2} (see Figure 14).

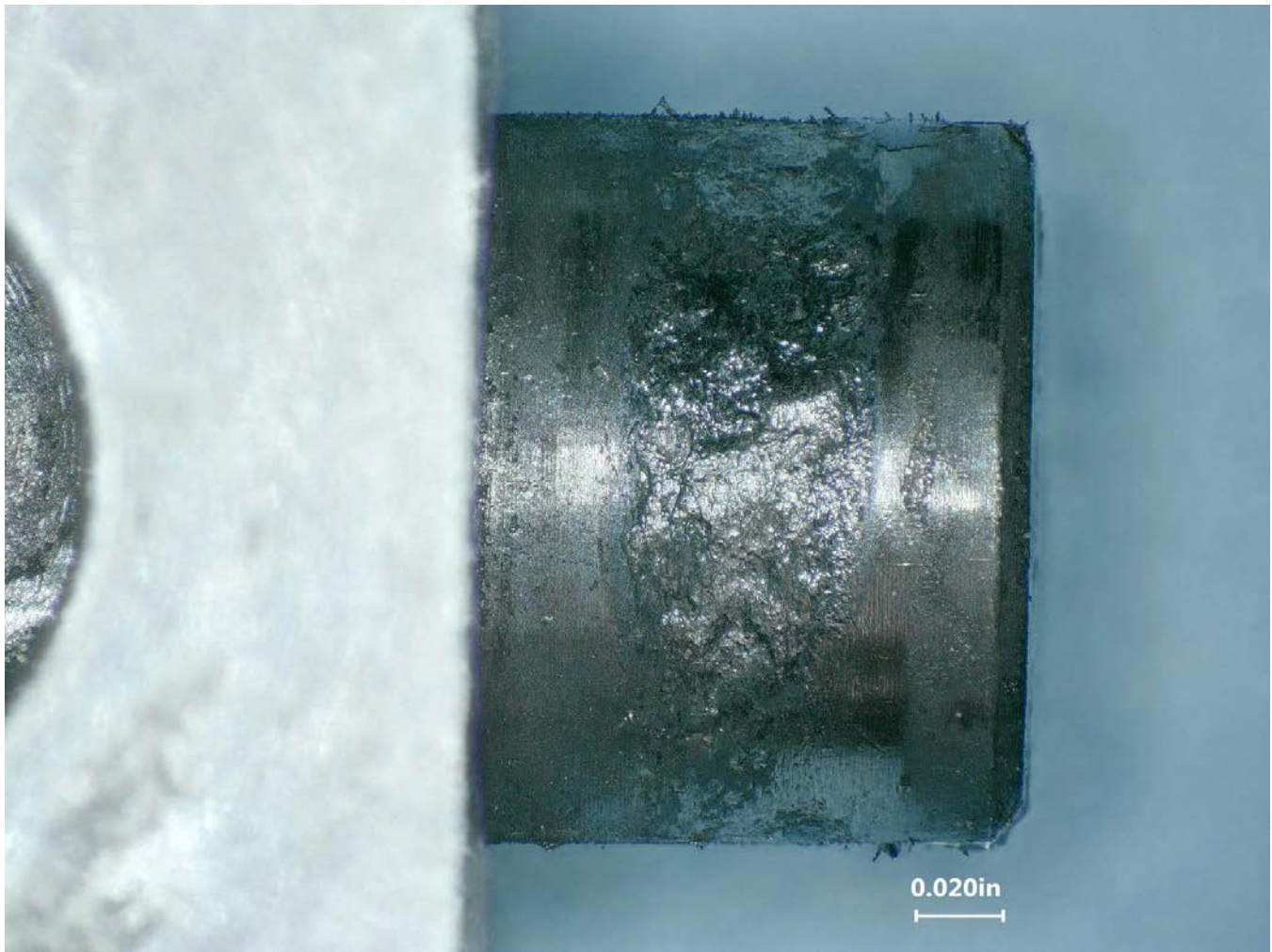


Figure 17 Digital microscope image of the center pin portion that is inserted into the cross-drilled hole in ear VY_{ear1} (see Figure 14).

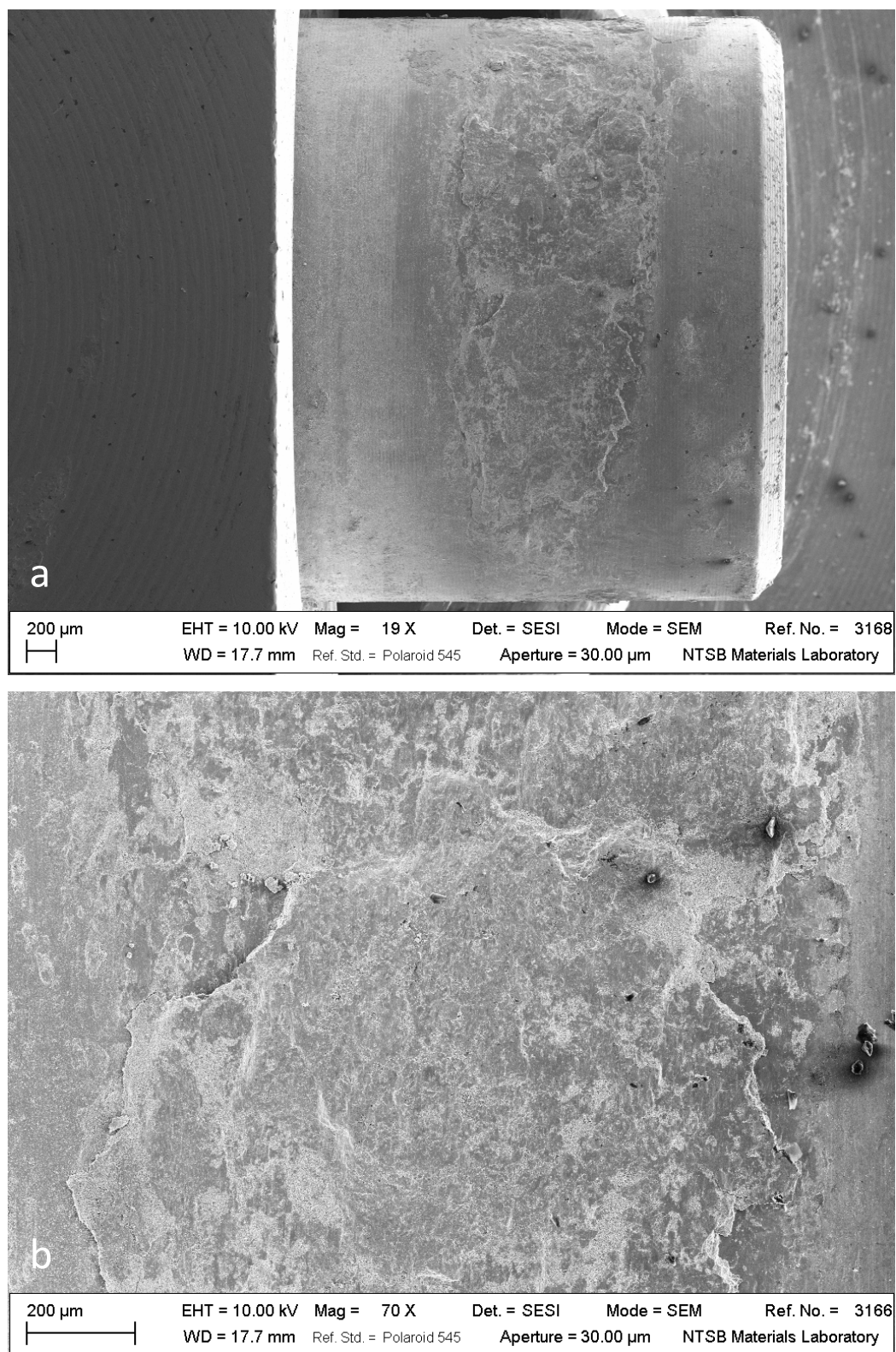


Figure 18 Secondary electron scanning electron microscope images of the center pin portion that is inserted into the cross-drilled hole in ear VY_{ear1} (see figure 14).

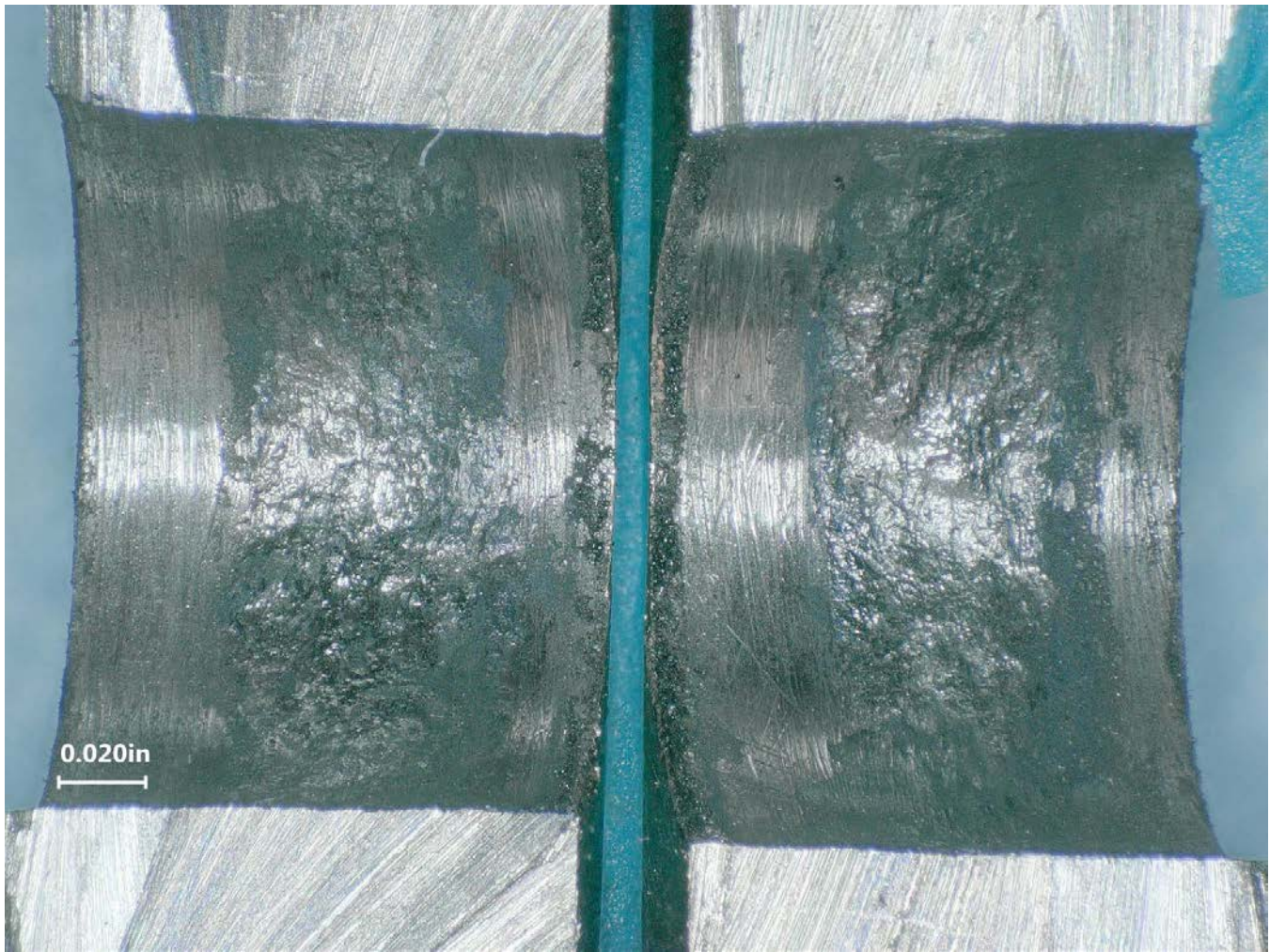


Figure 19 Digital microscope image of surfaces of the cross-drilled hole in ear VY_{ear1} (see Figure 14).