

NATIONAL TRANSPORTATION SAFETY BOARD

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



May 29, 2019

MATERIALS LABORATORY FACTUAL REPORT

Report No. 19-017

1. ACCIDENT INFORMATION

Place : San Manuel, Arizona
Date : May 21, 2018
Vehicle : Rhoads Autogyro MTO Sport, N574BR
NTSB No. : WPR18LA158
Investigator : Samantha Link, AS-WPR

2. COMPONENTS EXAMINED

Pieces of a propeller hub assembly
Fragments of a propeller blade

3. DETAILS OF THE EXAMINATION

On May 21, 2018, about 0845 mountain standard time, a Rhoads Autogyro MTO Sport experienced severe vibrations and a total loss of engine power during the initial climb from the airport at San Manuel, AZ. The certified flight instructor and student pilot were not injured. The gyroplane sustained substantial damage to the main rotor system. The flight instructor reported that after takeoff she heard a loud bang followed by severe vibrations and a total loss of engine power. Further examination of the gyroplane revealed that one of the propeller blades and part of the propeller hub were missing. The fractured blade, a second blade, and the remainder of the hub were sent to the NTSB Materials Laboratory for further examination.

Figure 1 shows the fractured propeller blade, as received. The propeller material was consistent with a fiber-reinforced composite. The blade had fractured in two locations: a transverse fracture across the blade cross section located approximately 5.5 inches from the base, and longitudinally through the foam core in the center of the blade. The longitudinal fracture of the blade was generally interlaminar in nature (between plies of the composite) but was not exclusively confined to one location—this fracture alternated between different plies, consistent with overstress separation.

Figure 2 shows the transverse fracture surface from the root side. This fracture exhibited fiber pullout and fractures at multiple heights, along with a central metallic tube that had buckled and collapse. The fracture of the internal tube exhibited a rough surface texture, and a general 45° slant in orientation. The tube material adjacent the tube fracture

had thinned (necked) but also exhibited deformation in multiple locations. These features were consistent with overstress fracture under variable loading orientations, consistent with typical subsequent fractures in airplane accidents. Figure 3 shows the root of the blade. The periphery of the angled root seat exhibited chatter marks, consistent with repeated load impulses on the part from contact with the adjacent hub seat.

Figure 4 shows the forward and aft faces of the propeller hub remnant, as received. The three propeller blade root seats had been labeled “1-2”, “2-3”, and “3-1” upon receipt. In addition, the locations of the bolts that connected the aft and forward halves of the hub had been labeled 1 through 6. This nomenclature was retained for the purposes of this report.

As shown in Figure 4, the hub had fractured about the 1-2 location where one of the propeller blades had sat. In addition, there was a large crack about the 2-3 position, illustrated in Figure 4b. The fracture about the 1-2 position is shown in Figure 5. The fracture occurred inboard of the #6 bolt position, such that that bolt and material outboard had separated. Figure 6 shows a closer view of the 1-2 crack, showing crack arrest (or beach) marks, consistent with progressive cracking. In addition, this fracture surface exhibited ratchet marks, consistent with multiple crack initiation sites.

Figure 7 shows a closer view of the 2-3 crack present that was on the aft half of the propeller hub. The remaining bolts were removed, the hub halves were separated, and the cracked hub section at the 2-3 position was intentionally overstressed (laboratory opened) to reveal the mating crack faces (displayed in Figure 8). Similar to the 1-2 fracture, the 2-3 crack faces exhibited features consistent with progressive fracture. Figure 9 shows a closer view of one of the 2-3 crack initiation sites, located at the propeller blade root seat.

Both the 1-2 fracture surface and the 2-3 crack were further sectioned and cleaned with acetone in order to examine them using a scanning electron microscope (SEM). Figure 10 shows a typical area of the progressive region of the 1-2 fracture. This area exhibited fatigue striations, consistent with fatigue crack propagation. A closer view of the striations is shown in Figure 11. These striations were also present towards the end of the fatigue crack, along with secondary (out of plane) cracking, as illustrated in Figure 12. A closer view of the striations at the end of the fracture is shown in Figure 13—the finely spaced striations were consistent with high-cycle fatigue (typical of repeated high-RPM propeller loads).

One of the 1-2 fatigue crack initiation sites is illustrated in Figure 14. The crack initiated at the 1-2 blade root seat. As shown in the figure, there were other smaller secondary cracks below the main fracture, consistent with the multiple crack initiation sites seen on the rest of the fracture. A closer view of the blade root seat at the 1-2 position is shown in Figure 15. This surface exhibited a network of corrosion pits. These pits often contained small cracks, as illustrated in Figure 16.

Examination of the 2-3 crack revealed similar features—fatigue striations were found throughout the progressive regions of the opened crack, as typified in Figure 17.

The fatigue crack initiated at multiple locations, such as displayed in Figure 18. As shown in Figure 19, this fatigue crack initiation site was located at a corrosion pit. Much like on the 1-2 blade root seat, the 2-3 blade root seat contained a network of corrosion pits (Figure 20 and Figure 21).

Part of the 2-3 fracture surface was cross-sectioned, mounted, and polished. A typical area of a cross section of the blade root seat surface is illustrated in Figure 22 and Figure 23. Corrosion pits were prevalent along the surface, typically located where grain boundaries intersected the surface. Subsurface cracks were observed, consistent with having propagated from the surface inward along grain boundaries (see Figure 23). These cracks were consistent with having initiated at surface corrosion pits.

The chemical composition of the mounted and polished hub cross section was inspected using energy dispersive x-ray spectroscopy (EDS) and x-ray fluorescence (XRF). The composition was consistent with a 300-series aluminum casting alloy. The hardness of hub was inspected per ASTM E18, and the electrical conductivity was inspected per ASTM E1004.^{1,2} The hardness averaged 39 HRBW. The conductivity averaged 41.2 %IACS. These data were consistent with those typically reported for as-fabricated cast aluminum products of this composition.³ A typical area of the internal hub microstructure is shown in Figure 24. The microstructure exhibited a dendritic morphology with bluish-colored interdendritic phases, typical of this alloy in the as-cast condition.

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¹ ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

² ASTM E1004 – *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. ASTM International, West Conshohocken, PA

³ “Properties of Aluminum Castings.” *Metals Handbook Desk Edition*, 2nd ed., J.R. Davis, ed., ASM International: Materials Park, OH (1998) pp. 489-498

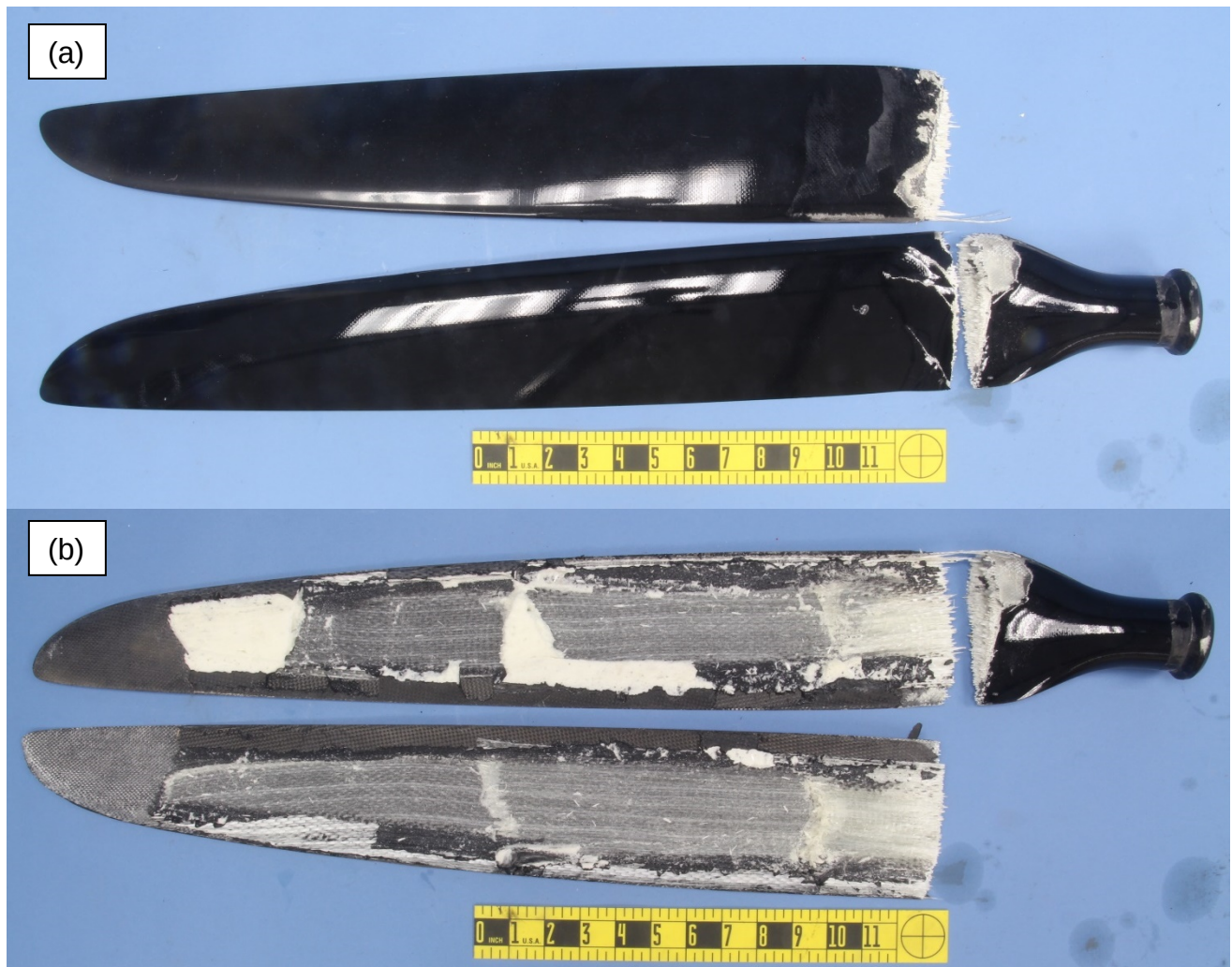


Figure 1 – View of the fractured propeller blade viewed from (a) the outer surfaces and (b) in internal, longitudinal fracture. The blade also exhibited a transverse fracture 5.5 inches from the root base.



Figure 2 – The transverse fracture surface of the propeller blade, showing fiber fraying and pullout, with tearing of the skin and internal foam core.



Figure 3 – The base of the fractured propeller blade, showing chatter marks on the seat ridge.

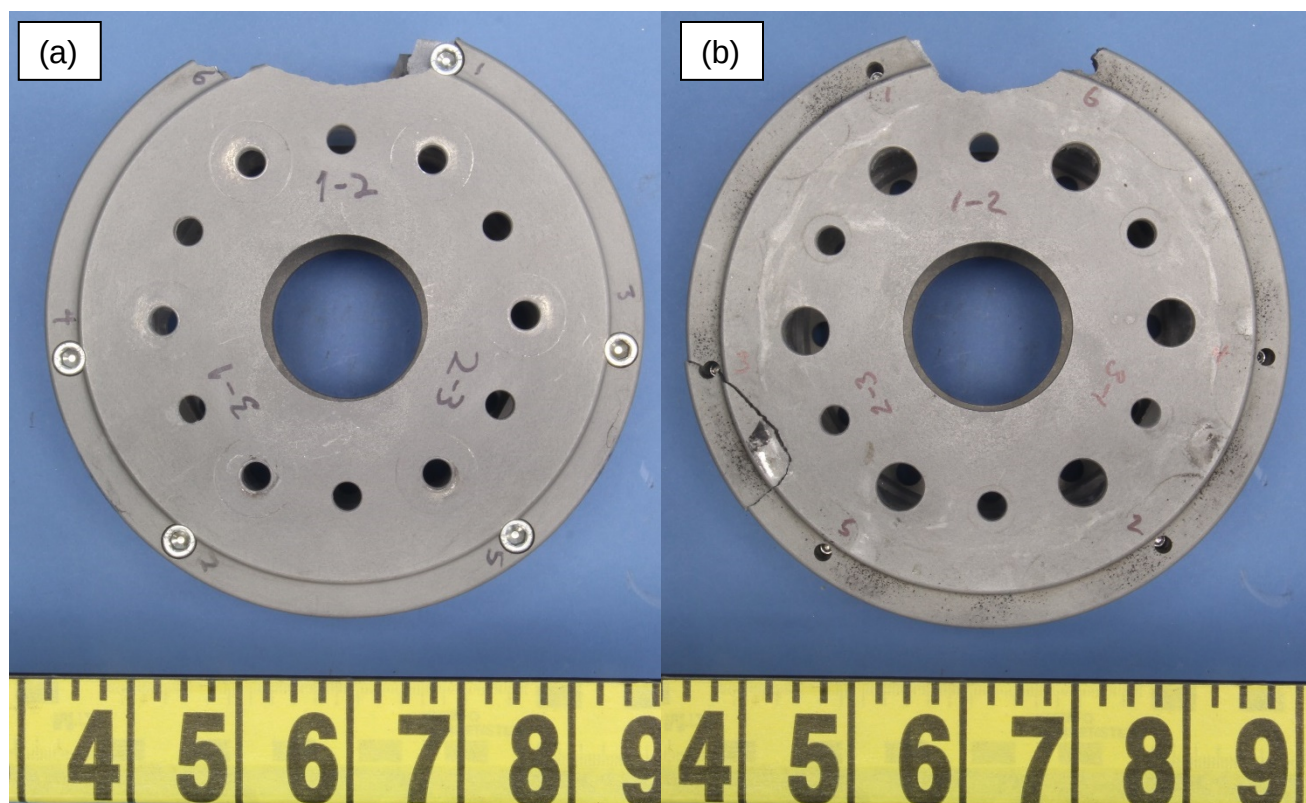


Figure 4 – The remnants of the propeller hub, as received from (a) the forward face and (b) the aft surface. The propeller blade seats had been labeled 1-2, 2-3, and 3-1.



Figure 5 – View of the fracture surface from the blade seat in position 1-2.



Figure 6 – View of the progressive region of the 1-2 fracture, showing crack arrest and ratchet marks.



Figure 7 – View of the cracked hub from the 2-3 blade seat position, viewed from the aft side.

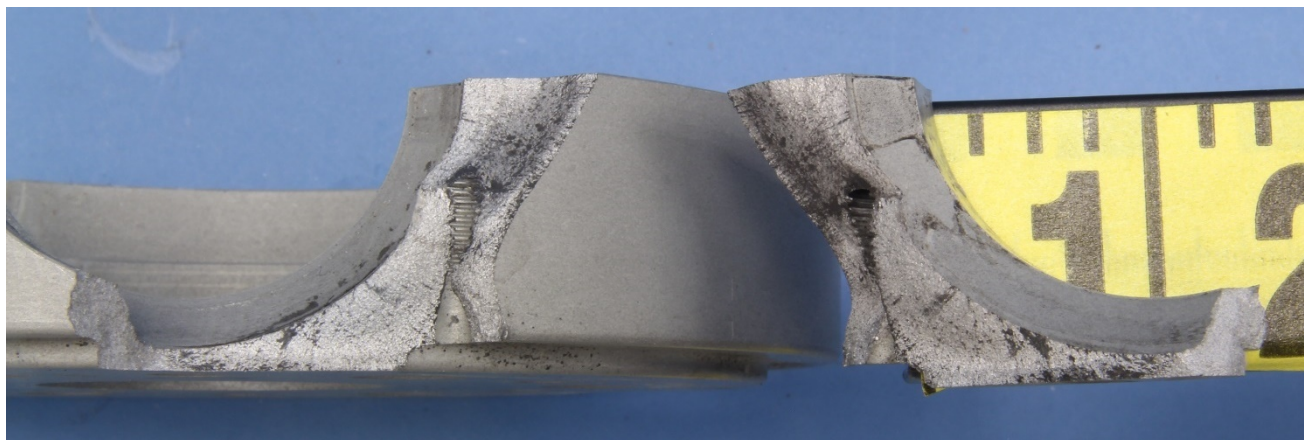


Figure 8 – Mating faces of the 2-3 fracture after separating the hub halves and lab opening the crack.

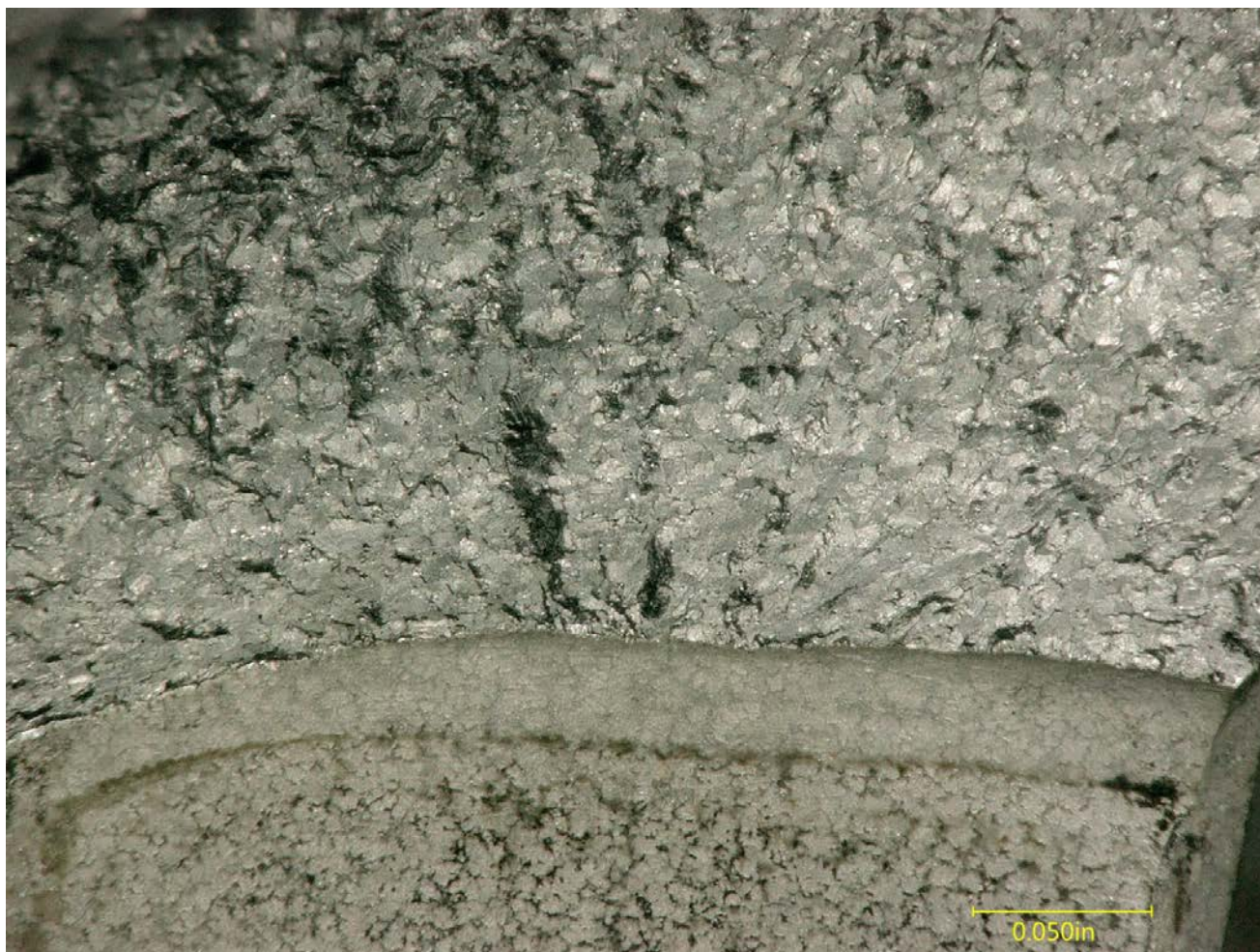


Figure 9 – Closer view of a crack initiation site on the 2-3 fracture surface, adjacent to the propeller blade root seat.

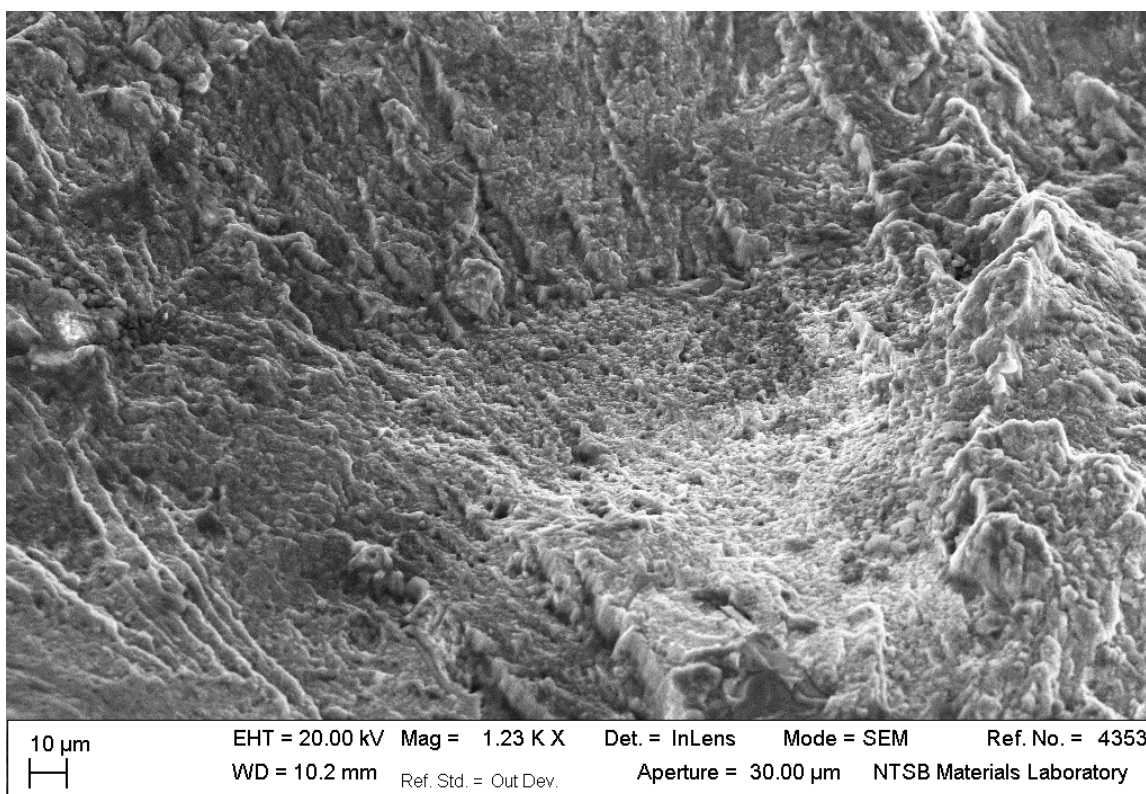


Figure 10 – Secondary electron (SE) micrograph of fatigue cracking near an initiation site of the 1-2 fracture surface.

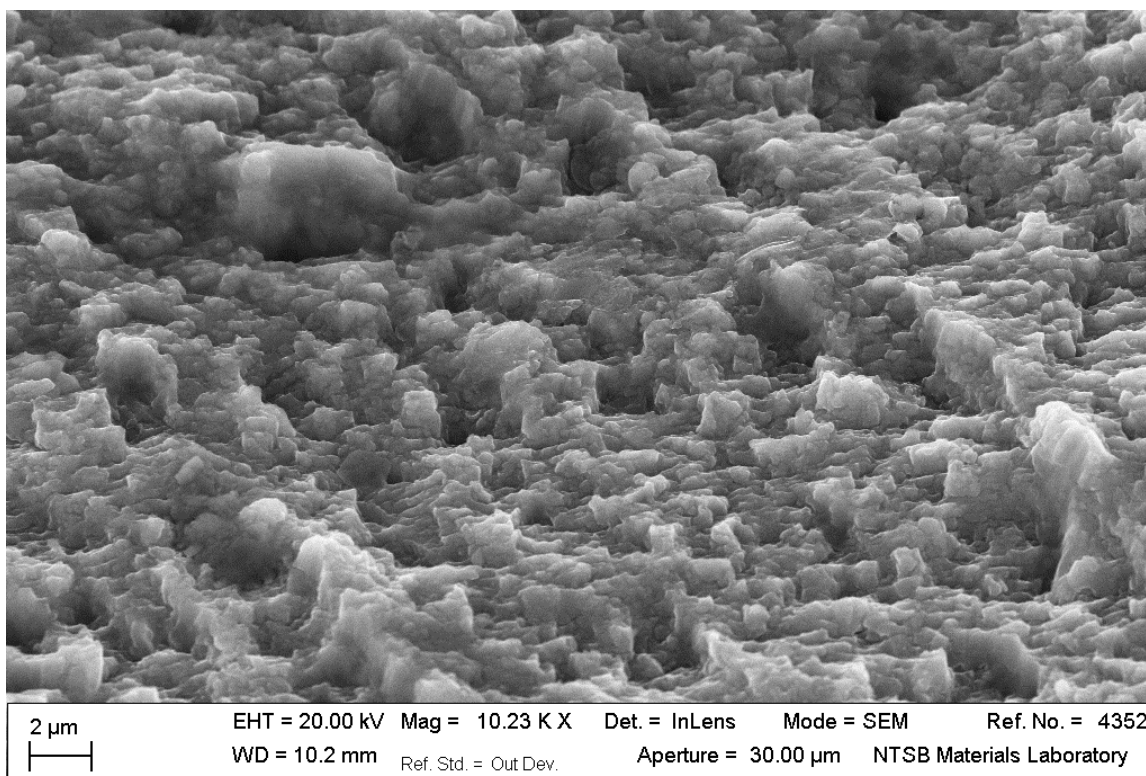


Figure 11 – SE micrograph of closer view of Figure 10, showing fatigue striations.

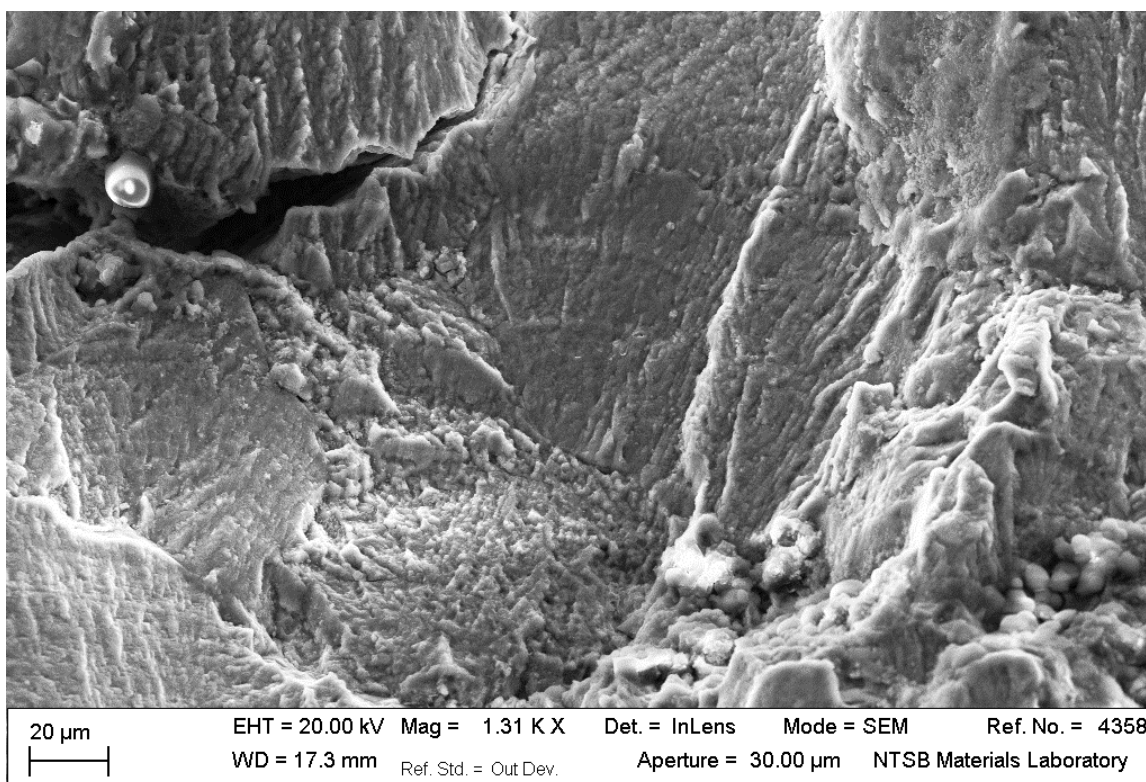


Figure 12 – SE micrograph of fatigue striations toward the end of the 1-2 fracture surface.

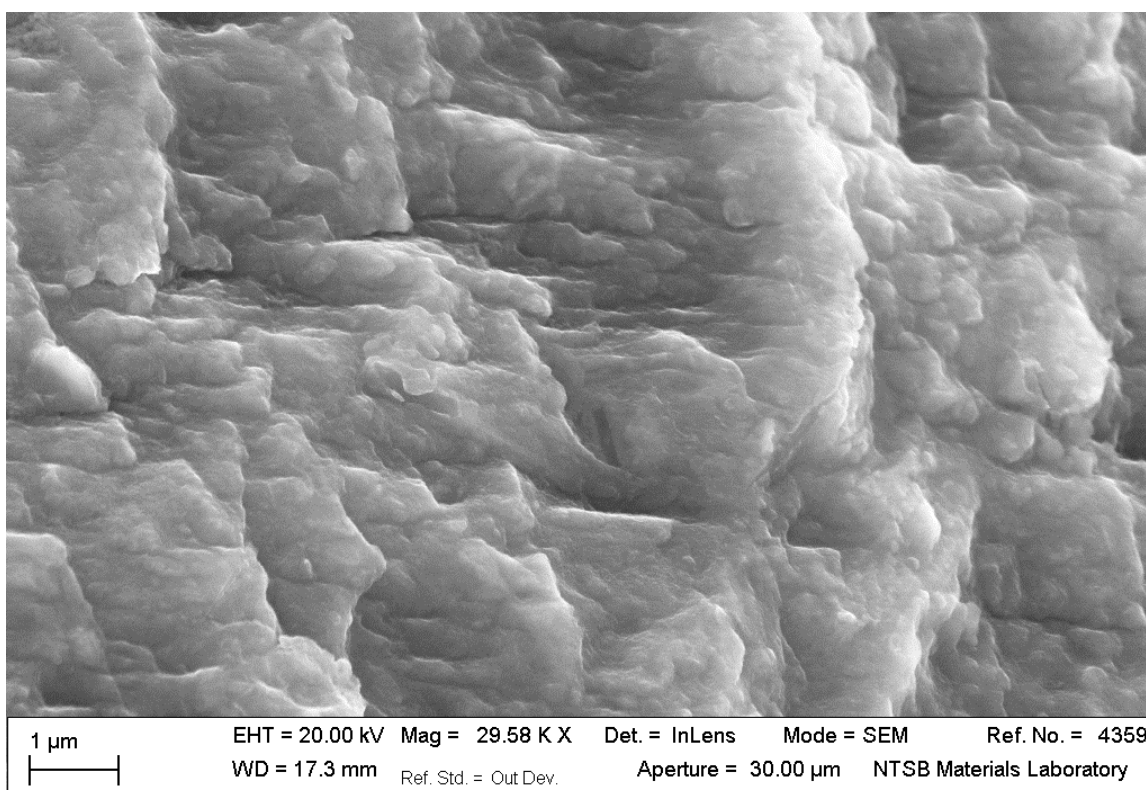


Figure 13 – SE micrograph of the fatigue striations in Figure 12.

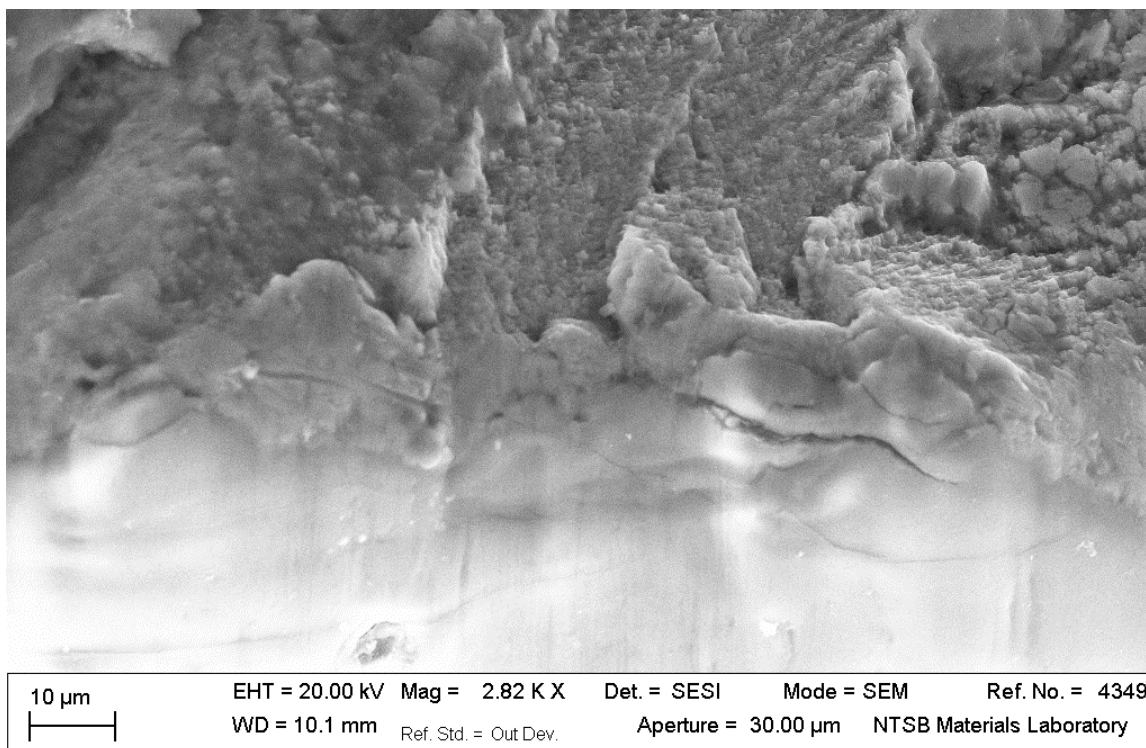


Figure 14 – SE micrograph of a crack initiation site on the 1-2 fracture surface, showing parallel cracking on the seat surface.

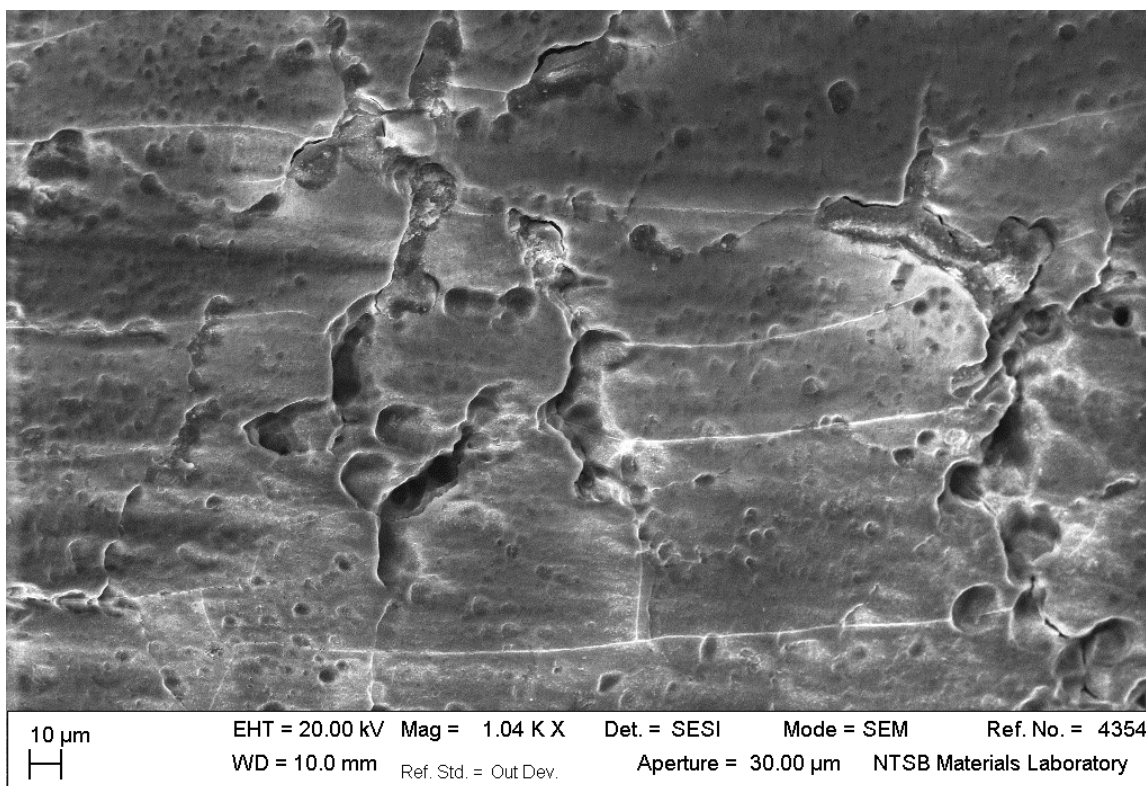


Figure 15 – SE micrograph showing the blade root seat of the 1-2 hole, revealing corrosion pitting.

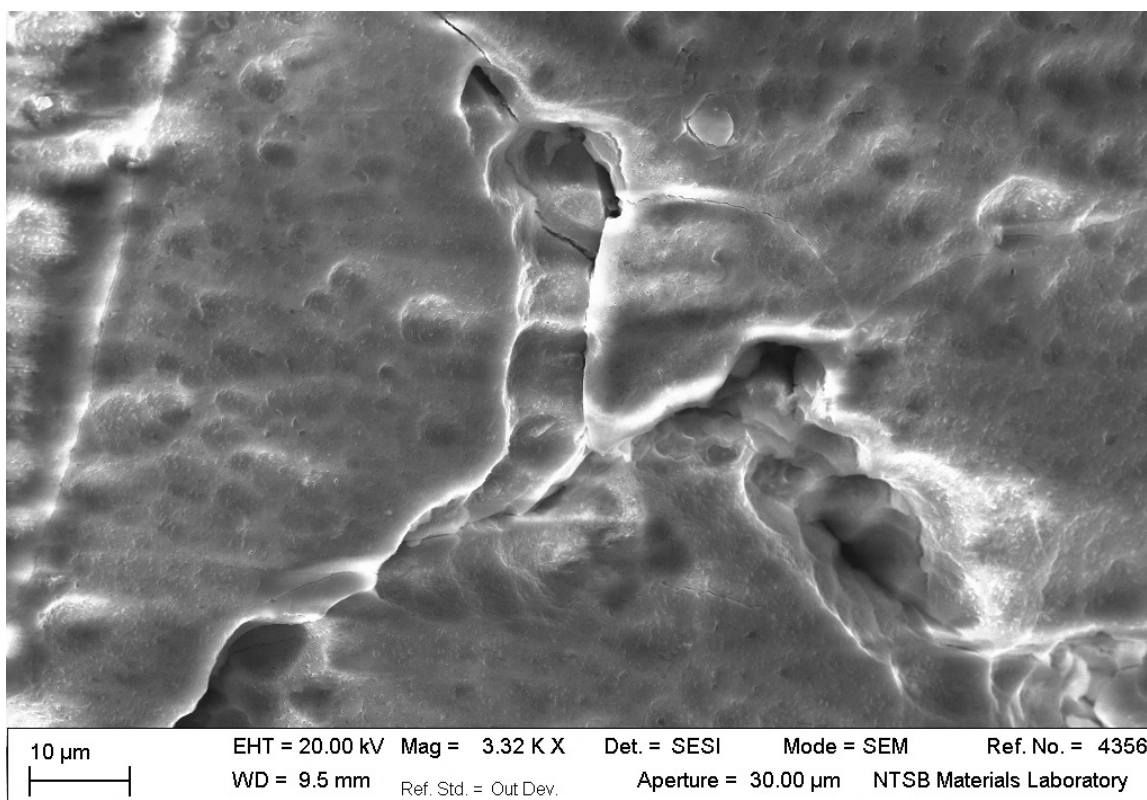


Figure 16 – SE micrograph of a closer view of corrosion pits on 1-2 blade seat.

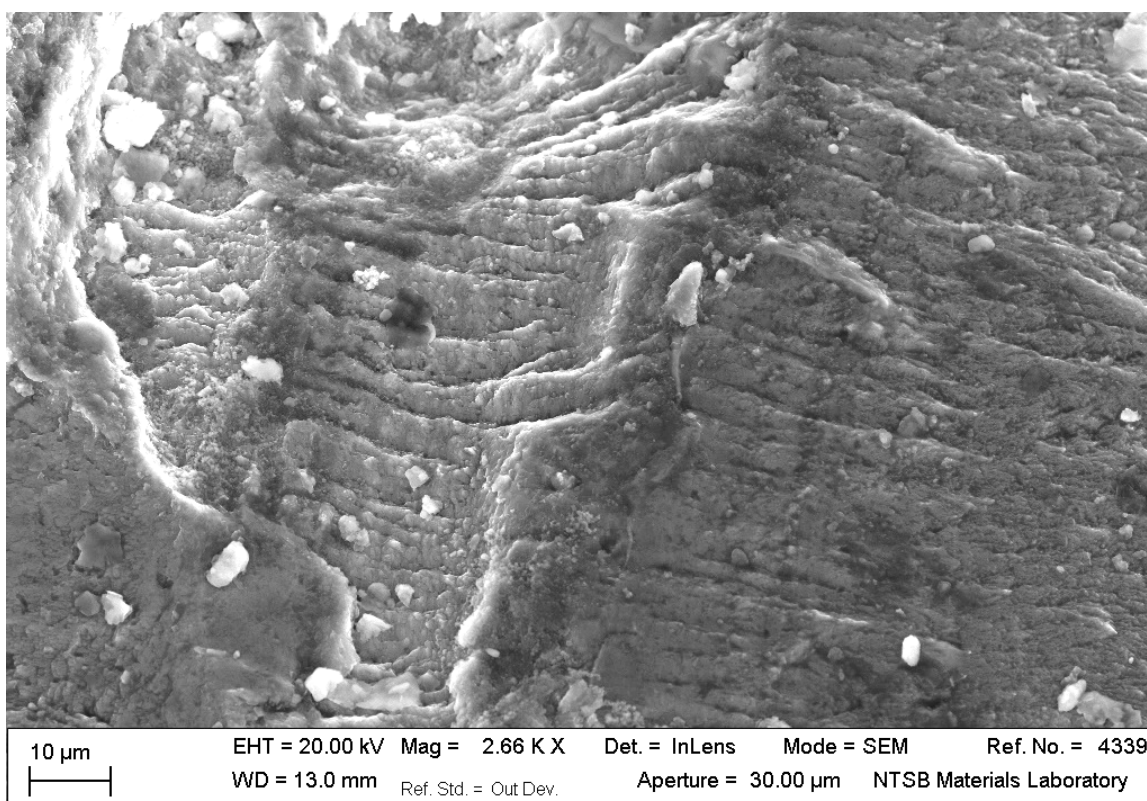


Figure 17 – SE micrograph of fatigue striations on the 2-3 crack, after lab opening.

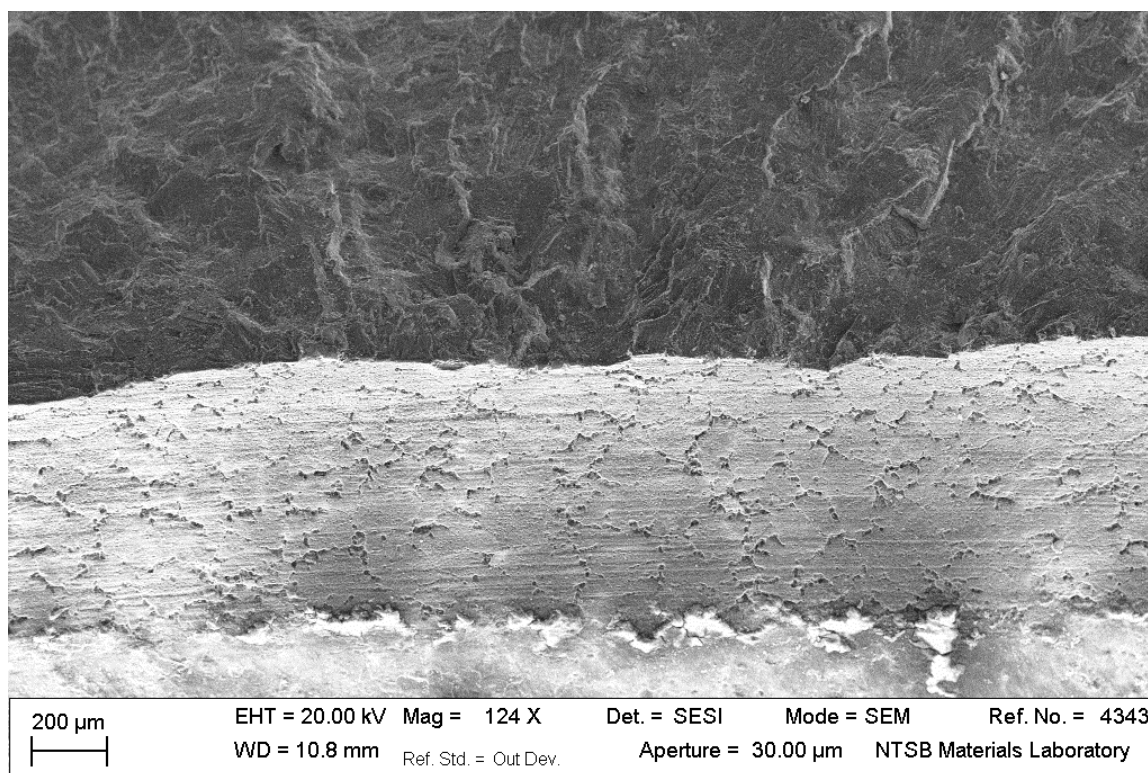


Figure 18 – SE micrograph of a fatigue crack initiation site on the 2-3 fracture surface.

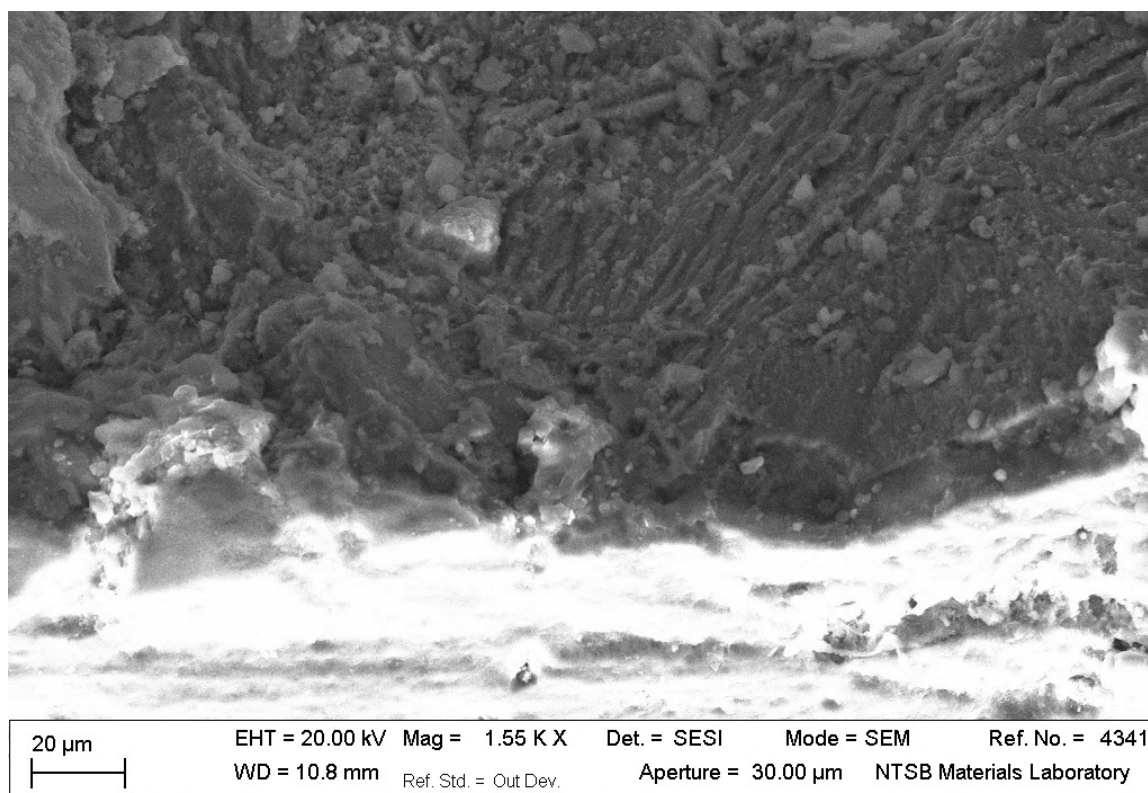


Figure 19 – SE micrograph of a fatigue initiation site on the 2-3 fracture.

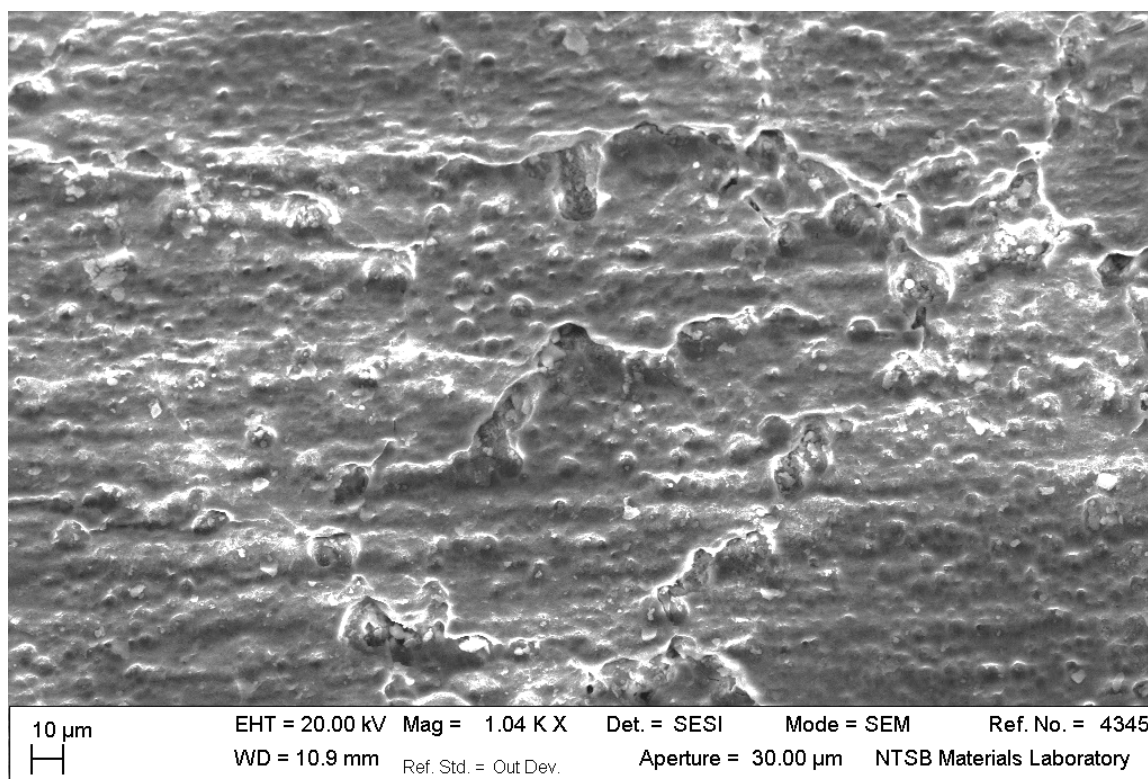


Figure 20 – SE micrograph of the blade root seat in the 2-3 position.

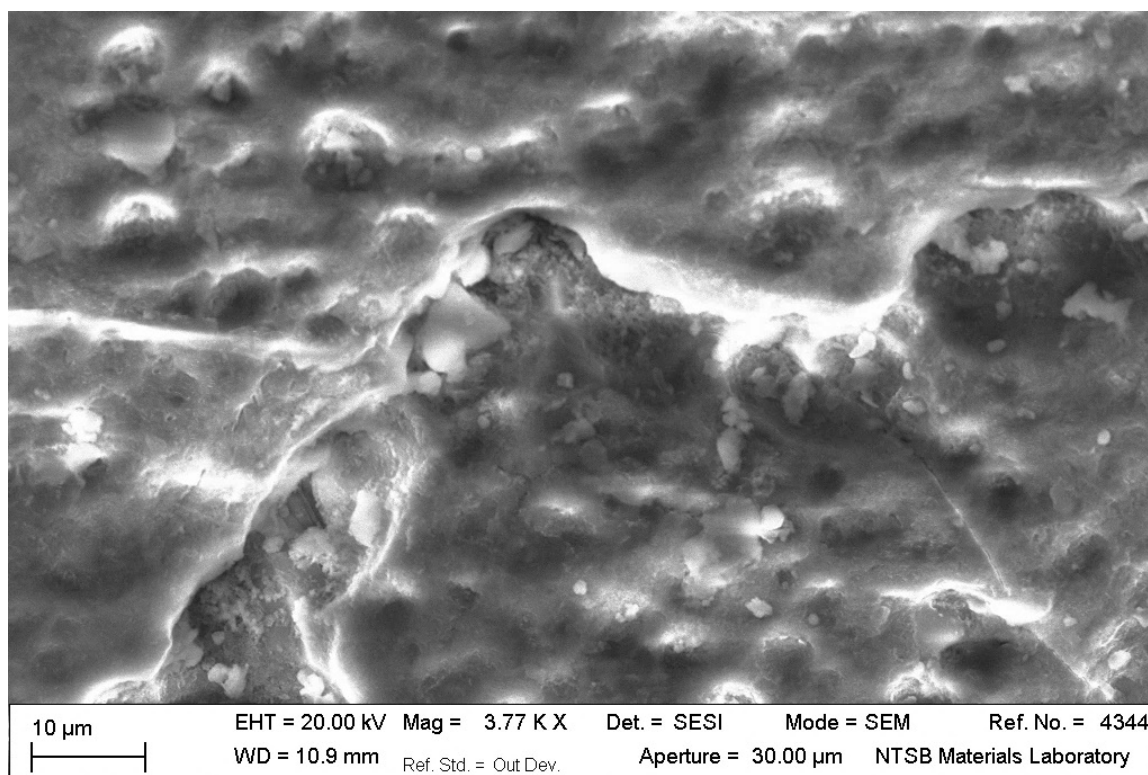


Figure 21 – SE micrograph of corrosion pitting on the seat of the 2-3 position.

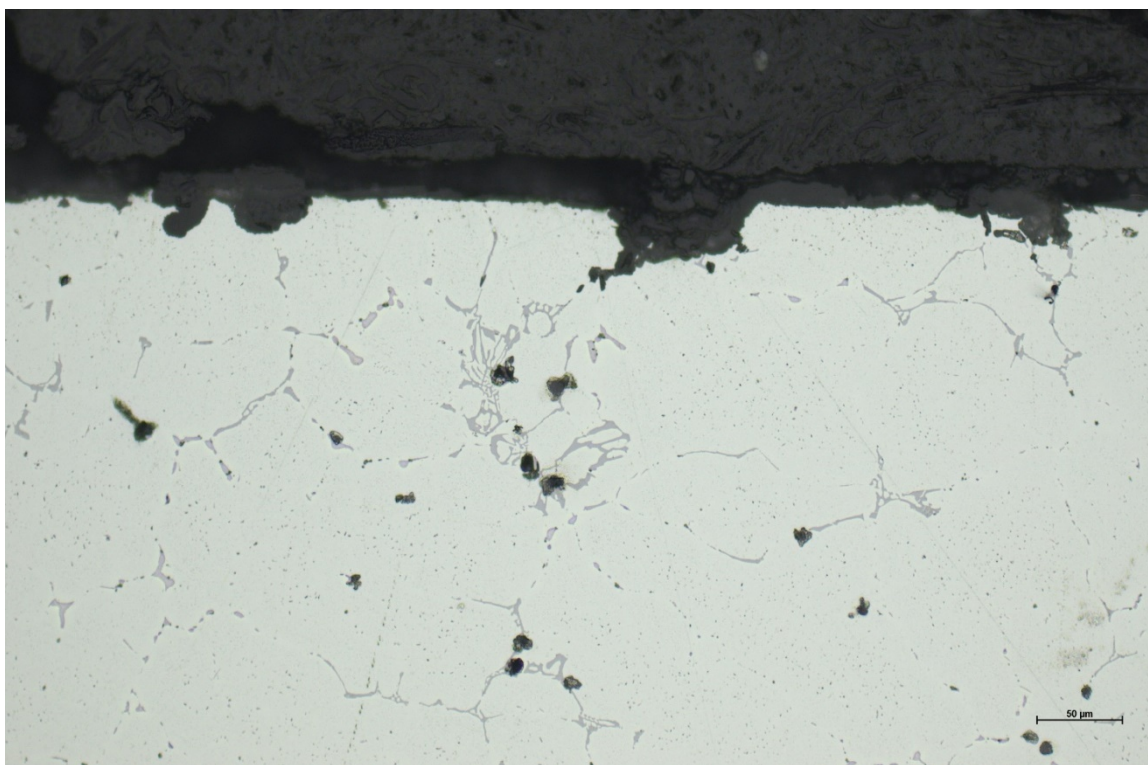


Figure 22 – Bright field (BF) optical micrograph of a cross section of the 2-3 hub bore surface, showing corrosion pits on the surface (~200X, as-polished).

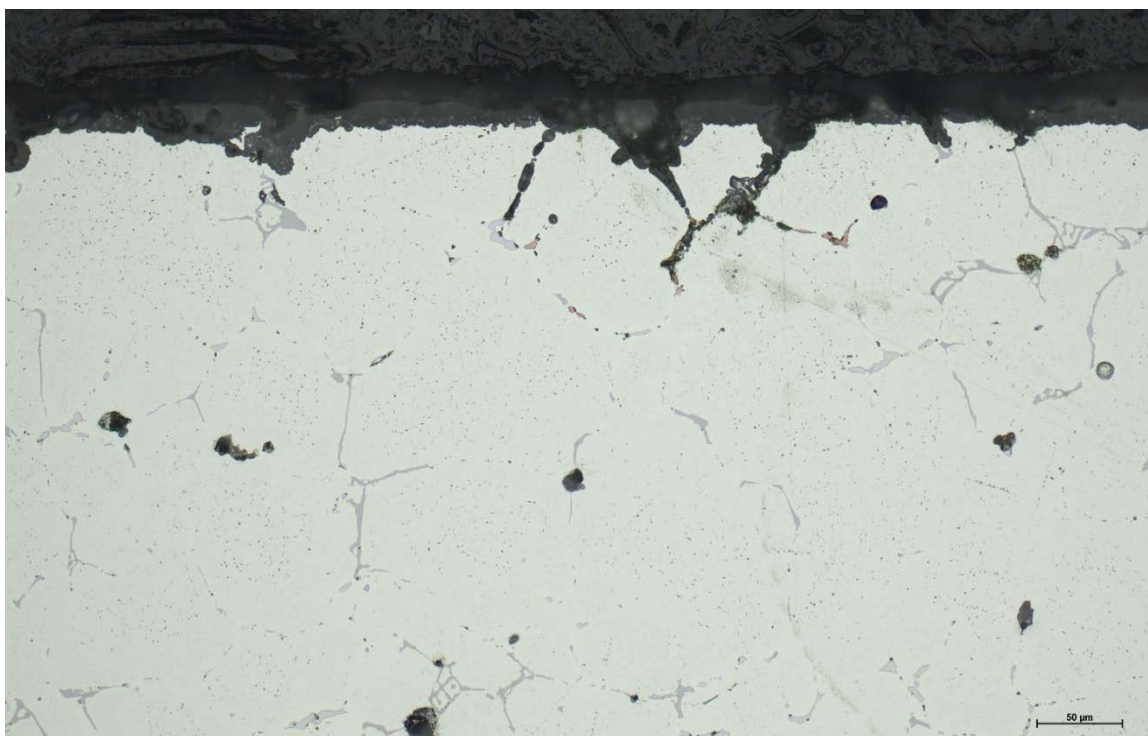


Figure 23 – BF optical micrograph of another area of the 2-3 blade seat surface, showing pitting and intergranular attack (~200X, as polished).

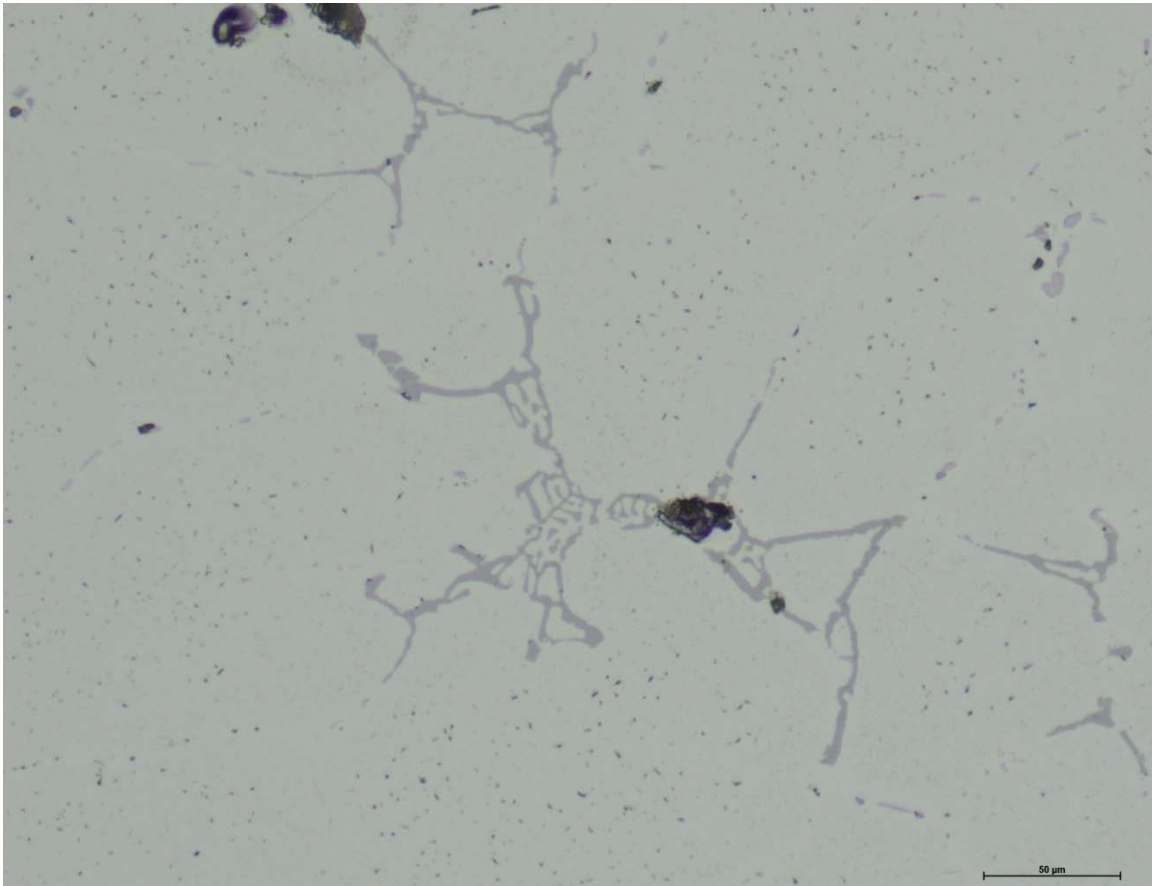


Figure 24 – BF micrograph of a typical area of the hub microstructure (~500X, as-polished).